WPI Farm Feasibility

This document contains the results of a WPI Farm Feasibility Study finding that a WPI Farm is in fact feasible.

Given the aim of determining whether a WPI campus farm is feasible, six conditions for feasibility (shown on the following page) were studied. From these considerations, ten groupings of the data were found (these are also shown on the next page) that together satisfy all six of the feasibility conditions.

The following document is structured to allow you to quickly traverse the portions of this study that are most interesting to you.

- The first page is composed of two columns. The first contains the six feasibility conditions, each one given its own color. The second column contains the ten data groups.
  - To the left of each of these groups are squares of color, one for each of the conditions the specific group supports.
  - To the right of each group is a bar of color. This is used to identify the following pages dealing with this group.
- The rest of the document is divided in sections, one for each group. Each section's color is that of the bar to the right of the group's icon on the first page.
  - Each section starts with a summary page that also details the organization of the section.
  - The following pages in each section contain the detailed data pertaining to the corresponding group.

Acceptability

Implementation

Demand

Practicality

Adaptation/Expansion

Integration

Variety

Financial Autonomy

Staffing

Land

Modules

Facility

City Benefits

WPI Interest

Markets

Projects

Land

Throughout the course of our study, we have identified several areas that could accommodate a WPI farm. The three lots presented in this section are within a two-mile radius from WPI and are easily accessible by public transportation.

The sections will proceed in the follow the order of:

1. **Gateway Park, WPI: a plot located on the WPI campus, over one acre in size.**
2. **65 Foster Street: a two-acre brown field near Union Station**
3. **Parking Lots on Madison and Gold Street: a one-and-a-half-acre plot near Kelley Square.**

Gateway Park

Establishing a farm at Gateway Park has significant advantages: first, the land there is owned by WPI; second, the land is a part on the WPI campus and is accessible to all students by a short walk; third, the location is visible from the Interstate-290 highway, and placing a WPI facility at that location will contributes to the school's publicity.

The main drawback of Gateway Park as a potential location for a WPI farm is the intended purpose of the land: specifically, the construction of new WPI facilities, Gateway 3 and Gateway 4.

Image taken from https://www.google.com/maps/

65 Foster Street

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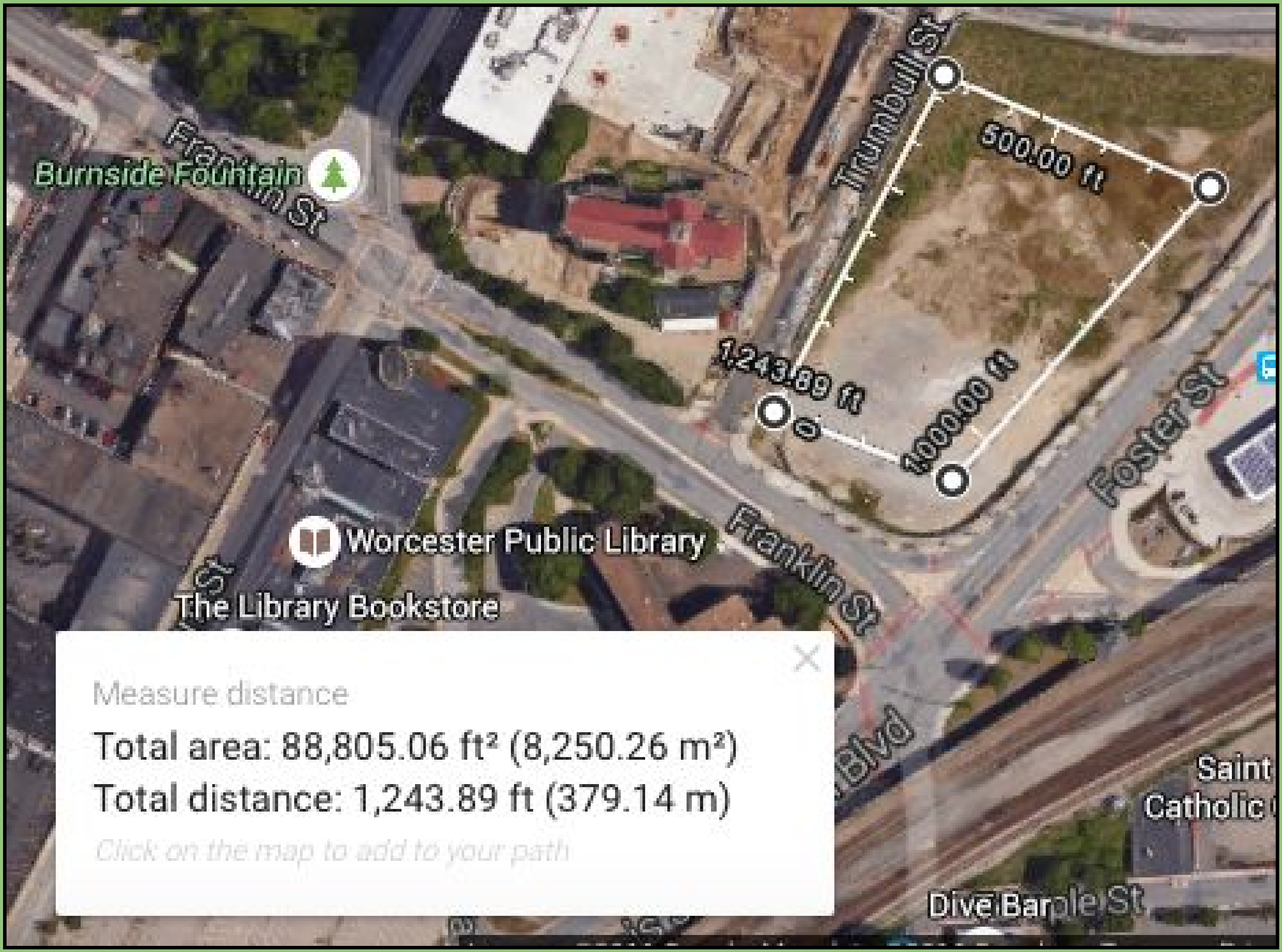


Image taken from https://www.google.com/maps/

Madison and Gold Street

After talking Daniel Racicot and mentioning the idea of using parking lots, he mentioned Kelley Square. The land there is already vegetated over and would be a spot that works for WPI as well as the city because the city is very interested in having a farm. That area is currently owned by Wyman and Gordon. We do not know how much it will cost to rent or buy from them because that requires negotiations with Wyman Gordon.

In terms of finding a location for a farm, we have yet to pursue a location. After having spoken with the city we know that there is certainly opportunity for land here in the city as there are several unoccupied or underused lots the city would like to see developed and the city is wanting to move in a direction that would see the rise of enterprises like urban farms in the near future. This evidence of opportunity is enough for the purposes of our study.

Image taken from https://www.google.com/maps/

Facility

The farm requires a facility and a set of equipment for a successful operation. To avoid soil remediation and prevent contamination, the plants require raised beds. Depending on the length of a growing season, the growing area needs to be enclosed in a greenhouse. Plant development requires irrigation, lighting, ventilation systems and heating during the winter season.

Based on an advice of a farm administrator from Community Harvest Project in N. Grafton, we have identified a set of equipment and suppliers necessary to fulfill these goals for a 3600 square foot plot of land (a unit) that could be adapted to either summer only or year-round growing. The total cost of setting up a summer unit is $16,600; starting a year-round operation requires $67,900.

Below, we present all equipment items we have selected and suppliers that sell them. The material is arranged as follows:

1. **Greenhouse Kit**
2. **Raised Beds Materials and Soil**
3. **Irrigation Equipment**
4. **Lighting Equipment and Fertilizer**
5. **Heating Equipment**
6. **Air Circulation Equipment**
7. **Equipment Lifetimes and Replacement**

Each section provides technical characteristics and a cost of supplying one unit with the type of equipment.

http://www.farmtek.com/farm/supplies/home

Greenhouse Kit

Greenhouse Kit: 30 by 60 feet greenhouse kit with double polycarbonate walls and slanted roof from FarmTek for $20,899 plus $4,450 for two end pieces -Pro Solar Star 2000.

Dimensions: 30 by 120 feet plot of land with two greenhouses arranged back-to-back.
The width of the greenhouse was set at 30 feet for two reasons. First, it is flexible and allows for installation of hydroponic (HP) units available from FarmTek. A lettuce HP unit, for instance, is 12 feet in width; two of these units will be freely accommodated in the greenhouse. The FarmTek dutch bucket HP system suitable for larger crops requires 30 feet of space.
Second, the selected width of 30 feet is small enough to maintain the unitary structure and scalability of the farm.

The length of 120 feet was chosen to be able to fit in most of the potentially available space in Worcester while maintaining the modularity of the structure and optimizing the space inside the greenhouse for maximum production. To achieve this length, two greenhouses are arranged back-to-back; the end pieces of the kits are can be bought separately and installed at each end of the setup.

Material and design: 8mm rigid twin wall polycarbonate; slanted roof design.
The material of the greenhouse has a good heat insulation (better than more common double plastic inflated walls) and rigidity to resist the wind. The slanted roof of the greenhouse prevents the accumulation of snow.

Greenhouse Kit	
Cost of 60'x30' Section	20899
Cost of Greenhouse End	2225
Number of Each	2
Total	**46248**

Greenhouse information taken from: http://www.farmtek.com/farm/supplies/home

Raised Beds and Soil

4 by 100 feet in length, 3 feet high, filled with compost; pressure-treated lumber walls from Home Depot; additional material: screws, hinges, all for a total cost of $2,735. Five beds per greenhouse for $13,675.

Dimensions: Due to the nature of the soil in Worcester and the cost of remediation, raised beds were chosen as a growing platform. In order to accommodate as many plants as possible, irrespective of root length, and in order to continue with the pattern of conservative estimates adopted for this report, the height of the raised beds was set at 3 ft. The width was estimated at 4 feet to accommodate most plants in reasonable space-efficient configuration without changing the width of the bed for every plant species. The length of 100 feet allows for 10 feet of storage space at both ends of the greenhouse. With 2 feet between bed rows and a foot wide gap between the planting space and the walls of the greenhouse, this allows for five such rows of raised bed in a greenhouse unit, as shown on the diagram.

In calculating the cost for one raised bed row, the price of 2 inch by 12 inch by 8 feet pressure treated lumber from Home Depot was used. The total amount of lumber necessary to enclose the perimeter of 1 bed (208 feet) up to 3 feet in height is $1,090. The approximate cost of additional materials, such as screws, hinges and extra lumber, cost $545.

For the soil, a mixture of Loam and Compost (priced equally at $25 per cubic yard) was selected from Mass Mulch.

COST PER RAISED BED	
Number of Pieces	78
Price per Piece	13.97
Cost for Pieces	1090
Cost Set Aside for Other Materials	545
Soil Cost per cubic yard	**25**
Cost for Soil	1100
Total	**2735**

RAISED BEDS	
Number of Bed Rows	**5**
Cost per Row	2735
Total	**13675**

Lumber vendor HomeDepot:
homedepot.com/p/WeatherShield-2-in-x-12-in-x-8-ft-2-Pressure-Treated-Lumber-255974/100022372
Soil vendor and prices: mass http://massachusettsmulchdelivery.com

Irrigation Equipment

Drip irrigation with drip tape connected through tubing to a 3 hp water pump was available for $1,600 from rainfloirrigation.com.

Drip irrigation system was chosen according to the advice of Ken Dion from Community Harvest Project in N. Grafton. The system is very affordable and water-efficient; it can operate autonomously and be controlled with a remote.

The drip irrigation tape was assumed to be stretched along raised beds, with four 100-feet-ling stripes per bed. Thus, the total length of tape needed for a greenhouse unit is 2000 feet. Additional tubing length necessary to connect the drip tape to the water pump was estimated at 300 feet per greenhouse. Connecting the components requires additional adaptors, ties, filters, etc. with all components listed at rainfloirrigation.com. Finally, one 3 horse-power water pump is necessary to supply water to the system.

The tape and tubing can be purchased in large batches, with one batch providing enough materials for multiple greenhouse units. The prices per greenhouse are given in the tables below.

ITEM	**COST, $**	**NUMBER per GREENHOUSE**
Water Pump (3 hp)	1475	1
Drip Tape	162 for 4100'	1/2
Additional Tubing	62 for 1000'	1/3
Adaptors, Holders etc.	20	1

IRRIGATION	
Price of 3 hp Water Pump	1475
Cost of 2050' Drip Tape	81
Cost for 333' of Tubing	21
Price for Adaptors, etc.	20
Total	**1597**

Irrigation equipment parameters suggested by Ken Dion, Operations Dir., Community Harvest, N.Grafton.
Irrigation equipment vendor and prices:http://www.rainfloirrigation.com

Lighting Equipment and Fertilizer

25 High Pressure Sodium Bulbs (1000 Watt) from FarmTek provide 130,000 lumens each

During the winter, a greenhouse requires a significant amount of supplemental lighting. The total required lighting per square foot of growing space in a greenhouse is 900 lumens (CITE). Therefore, 3.24 million lumens are needed to light the 3600 square feet of greenhouse area. The With 1000W High Pressure Sodium Bulbs from FarmTek, one gets 130000 lumens per bulb. Therefore, in order to light an area of 3600 sq-ft, one needs 25 such bulbs.

The bulbs come with fixtures and cost $153 each. The total cost calculation is shown in the Table below.

LIGHTING	
Lumens per Unit	130000
Required Lumens per sq-ft	900
Number of Units	**25**
Cost per Fixture	110
Cost per Bulb	43
Total	**3825**

FERTILIZER	
TOTAL COST	**200**
APPLICATION	
Nitrogen, lb/acre	100
Phosphorus, lb/acre	75
Potassium, lb/acre	125
Applications per Year	**8**
COSTS	
Price per pound	0.9
Area of application, sq-ft	3600
Price per application	25
TOTAL COST	**200**

Equipment information taken from: http://www.farmtek.com/farm/supplies/home
Light requirements taken from:
https://ag.umass.edu/fact-sheets/design-layout-of-small-commercial-greenhouse-operation

Heating Equipment

Modine 160M BTU PDP Greenhouse Heater available from FarmTek.

During the winter in Worcester, each of our winterized greenhouse units will need adequate heating to maintain the temperature. During the coldest month of the year in Worcester (CITE temperature data), in order to maintain a temperature of 80 F, 130000 BTU are required. At the suggestion of Ken Dion (CITE) we selected a Modine 160M BTU PDP Greenhouse Heater (which is sold by FarmTek). This unit alone produces 160000 BTU, thus, with adequate air movement, is capable of heating an entire greenhouse unit.

HEATING	
BTU per Unit (at 80%)	160000
Required BTU in Coldest Month	130000
Number of Units	**1**
Cost per Unit	1229
Total	**1229**

Air Circulation Equipment

Eight 20-inch ValueTech Horizontal Airflow Fans available from FarmTek at a total cost of $1,350.

To ensure a necessary level of plant hygiene and proper heat distribution throughout the greenhouse, an airflow of 8 CFM per square feet of greenhouse area has to be provided. This is achieved with nine 20-inch ValueTek Horizontal Airflow Fans available from FarmTech distributed throughout a greenhouse. Each fan provides 3300 CFM.

The selected fan is an optimal choice due to the relative low cost and an optimal airflow generation. Despite the availability of more powerful fans, using the one presented here ensures a steady, uniform flow of air at all location within the greenhouse.

FANS	
CFM per Unit	3300
Required cfm per sq-ft	8
Number of Units	9
Cost per Unit	150
Total	**1350**

Equipment information taken from: http://www.farmtek.com/farm/supplies/home
CFM/Heating: https://ag.umass.edu/fact-sheets/design-layout-of-small-commercial-greenhouse-operation

Equipment Lifetime

Equipment lifetimes and an average cost per year associated with replacing the equipment are presented in the table below.

EQUIPMENT LIFETIMES	
High Pressure Sodium Lamp	13
Lamp Fixture	15
Fan	7.5
Heater	10
Water Pump	15
COSTS	
High Pressure Sodium Lamps	1075
Lamp Fixtures	2750
Fans	1350
Heater	1229
Water Pump	1475
REPLACEMENT COSTS PER YEAR	
High Pressure Sodium Lamps	82.69
Lamp Fixtures	183.33
Fans	180
Heater	122.9
Water Pump	98.33
TOTAL COST	**667.25**

Equipment information taken from: http://www.farmtek.com/farm/supplies/home
Fan lifetime: http://orionfans.com/how-to-read-a-data-sheet/life-expectancy.html
Sodium lamp lifetime:
http://gro-kart.com/blog/2015/01/everything-you-ever-wanted-to-know-about-high-pressure-sodium-grow-lights/
Water pump lifetime: http://inspectapedia.com/water/Well_Pump_Life.php

Modules

One of the most important considerations about a WPI Farm is the modularity. A model built of small units can be easily scaled, moved, restructured and adapted to a new purpose. Facing the dynamic environment in the City of Worcester, the design of WPI farm incorporates a highly modular structure allowing the enterprise to join the collaborative effort to supply food to city residents while providing the opportunity for academic research and student projects.

The modular structure is made with 2 types of units: a summer only and a year-round that can combine to make up a farm of practically any size above 3600 square feet with any desirable mode of operation. This section describes the elementary block (units/modules) of the model, discusses the advantages of using one and provides an operational tool to use the unit in generating adjustable models. The material is arranged in the following order:

1. Unit Composition
2. Design Advantages
3. Models

Unit Composition

The modularity of the farm is achieved by building a structure that is comprised of several unbreakable elementary units of two kinds: one that operates only during the summer season, and the other that is open during a full year. At the core of each unit is a 120 by 30 foot plot of land* with all the infrastructure required for its operation, including. Units of both types include raised beds that are 3 feet high by 4 feet in width and 100 feet long. The raised beds are filled with compost and loam mixture. The unit intended for a year round operation includes a greenhouse, lighting, heating, and air circulation equipment in addition to all necessary irrigation equipment and farming tools. All equipment associated with each type of unit is listed in TABLE.

All equipment required for the operation of a unit comprises its setup cost. Once in a working condition, the unit requires maintenance and labor, and is able to produce a revenue based on the available growing area of 2000 square feet. To maintain the conservative nature of estimates in this study, the revenue is estimated at 50% of the production capability. Using the units (greenhouses) and the associated setup, maintenance, labor costs, and revenue, any farm operation can be described in terms of number and kind of units involved.

UNIT TYPE	EQUIPMENT	MAINTENANCE	LABOR
Year-round	Greenhouse structure, Raised beds, Irrigation equipment, Lights, Heaters, Fans	Fertilizer, Water, Electricity, Heating	6 month per year, farm manager, volunteers, Work-Study
Summer	Raised beds, Irrigation equipment, Fertilizer, Electricity, Water	Fertilizer, Water, Electricity	12 month per year, farm manager, volunteers, Work-Study

Design Advantages

The modularity of the farm has several advantages that make the enterprise versatile:

1. Scalability. The farm can be extended or shrunk according to WPI intentions. It can serve as a small experimental garden and include only a few units or be expand to supply a neighborhood with local produce.
2. Purpose. Each unit can serve its own purpose independent from those of other units.
3. Mobility. Implemented using equipment kits, the farm can be easily relocated according to the space availability and proximity to the product destination.
4. Distribution. A mobile structure can be adjusted to the distribution needs and the availability of the work force. The farm can supply local produce to vendors, or provide produce to undernourished neighborhoods and food deserts directly.

Models

Any farm, starting from a small 3600-square-foot plot of land, and up to many-acre operation, can be characterized - and implemented - using the modular structure presented here. Several examples of farm models designed with the above units are shown in the TABLE (all numbers given per year). Summer units column indicates the total number of units on a farm; Winder units shows how many of the summer units will be open during full year (i.e. will have a physical greenhouse structure). The revenue column presents the revenue of the farm assuming only 50% of all grown produce is sold. Taking into account the operating and labor cost, the revenue can be converted to profit. If the initial investment (i.e. the setup cost) is to be recovered with the generated profit, it will take the number of years indicated in the Payoff Time column.

Summer Units	Winter Units	Payoff Time	Set-up Cost	Operating Cost	Labor Cost	Revenue	Profit
5	0	8	83000	9500	33000	53000	10500
8	0	4	132800	15200	33000	84800	36600
12	0	3	199200	22800	33000	127200	71400
9	1	17	200700	33100	66000	111200	12100
10	1	11	217300	35000	66000	121800	20800
12	1	7	250500	38800	66000	143000	38200
10	2	13	268600	51000	66000	137600	20600
12	4	14	404400	86800	66000	190400	37600

Staffing

During our study we have created multiple staffing possibilities. A full-scale farm requires a number of reliable staff members who will be working at the farm regularly. We have focused on having a full time paid farm manager along with student volunteers and a job that can help fund limited qualification workers for the Worcester County residents.

The sections will proceed in the following order of:

1. **Farm Manager**
2. **Student Volunteers**
3. **Veterans Inc.**
4. **Grafton Recommendations**
5. **Table on staffing**

Farm Manager

Our staffing ideas include either a full-time farm manager who will be paid $63,000 per year with benefits. The other option is to have a farm manager only during the summer who will be paid $31,500 with benefits. The reasoning for a farm manager is to have someone at the farm at all times. They are also more knowledgeable on how to manage a farm and have experience working on one.

Student Volunteers

The plan for students is to have them as additional labor but not the main labor. For a full time farm operating in both summer and winter we would need 300 student working hours. If the farm is only open during the summer, then only 150 student-working hours is required. From a community survey and interviews with students, we have determined that the average student is interested in volunteering 1-3 hours a week. Having students volunteer work and participate in a paid Work-Study program will allow students and volunteers to have hands-on experience growing and maintaining crops.

Veterans Inc.

We spoke with John Person and he directed us to Aliya Ewing. She told us that Veterans Inc is always looking for possible employment for their clients so having a farm so close by would be a great opportunity for those that are interested. Aliya believes that, overall, the clients and residents want to feel connected and engaged and a community farm or campus farm would have the potential to increase the engagement and the overall well being of the clients and residents. As for the produce a farm produces, Veterans Inc. is open to any cost-effective ways for providing foods for their clients and residents.

Labor data supplied by Ken Dion, Operations Dir., Community Harvest, N.Grafton.
Veterans inc information obtained from John Person and Aliya Ewing via email.

Grafton Recommendations

Based on an interview with a professional farmer, a farm will need about 150 volunteer hours to maintain a farm only operating in the summer. If a farm is operating year round then around 300 volunteer hours are required. He also mentioned that we don't need to have a full-time farm manager in the beginning but the farm begins to expand more than a full-time farm manager will be required.

Table on Staffing

From the table above, additional labor will be paid $10 per hour and on the right column is the total amount that is dedicated to those additional labors.

In conclusion, we have decided on having a full time farm manager to ensure the farm has the best chances of growing and surviving. The other labor will hopefully come from student volunteers and, if not, then workers from Veteran's Inc.

For the actual notes on the interviews from which this data was gathered, refer to the appendices.

FARM MANAGER (INCLUDING BENEFITS)	
Full Year	63000
Summer Only	31500
ADDITIONAL LABOR	
Wage per Hour	10
Full Year (300hrs)	3000
Summer Only (150hrs)	1500
TOTAL (FULL YEAR)	66000
TOTAL (SUMMER ONLY)	33000

Variety

Following are examples of plant species and their varieties growable in New England temperatures and conditions.

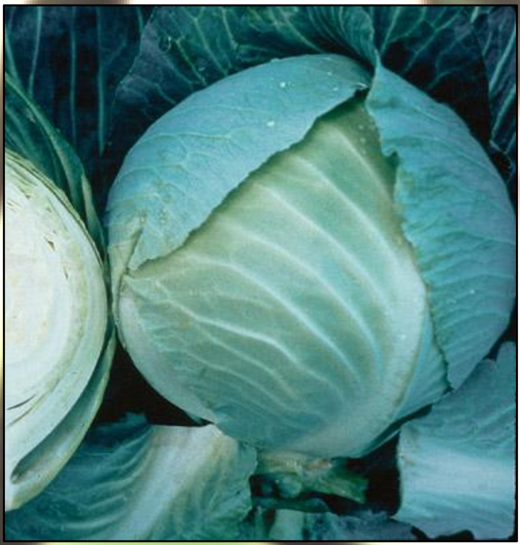
Statistics

- # of plants and lbs of produce are based on five feet of four foot wide row
- Revenue is based on the above with current market prices and the assumption that 50% of produce is sold
- # of growing cycles is per growing season

Pictures and variety names taken from Johnny's Selected Seeds
Prices taken from the USDA
Other numbers are conservative values from a number of hobbyist sites:
http://www.johnnyseeds.com/
http://homeguides.sfgate.com/
http://www.almanac.com/
http://forums.gardenweb.com/

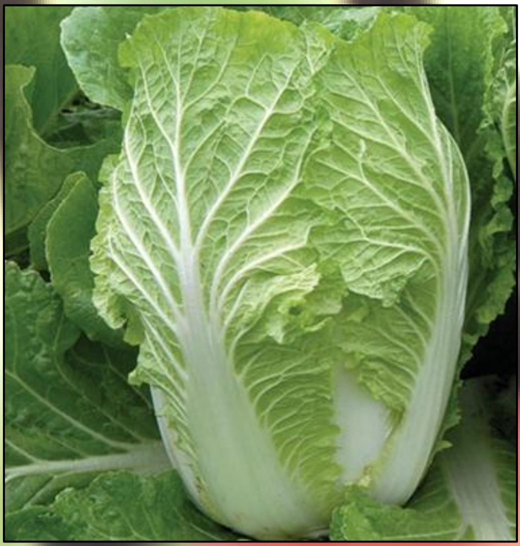
Beets
80 plants
20 lbs produce
13 ($) revenue
3 growing cycles


Red Ace


Storage No. 4

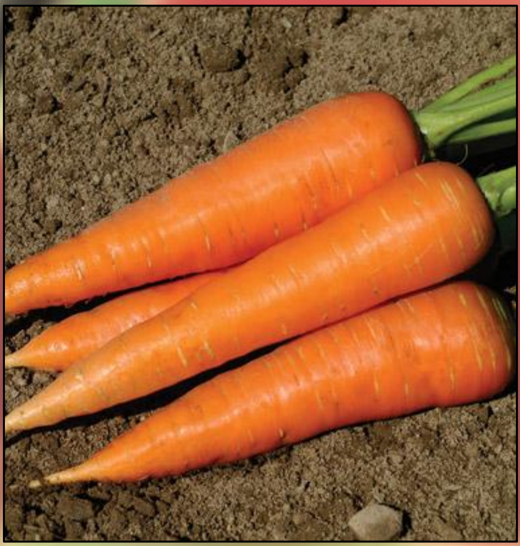
Cabbage
7 plants
14 lbs produce
7 ($) revenue
2 growing cycles


Super Red 115


Rubicon

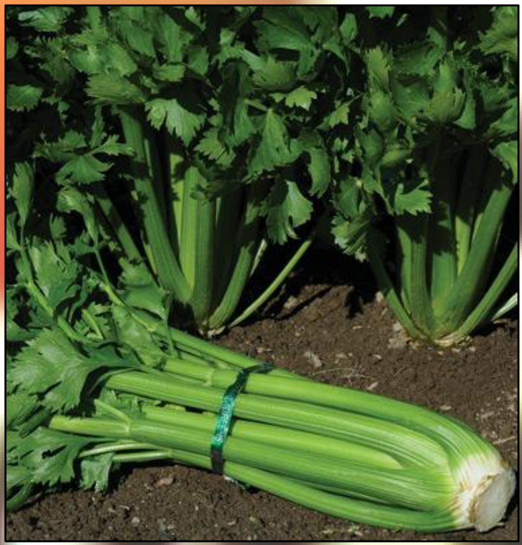
Carrots
120 plants
19 lbs produce
19 ($) revenue
1 growing cycle


Bolero


Hercules

http://homeguides.sfgate.com/
http://www.foodcoop.com/produce

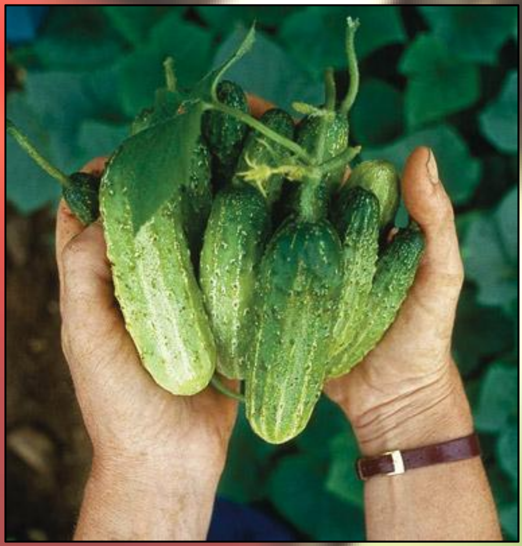
Celery
15 plants
15 lbs produce
8 ($) revenue
2 growing cycles



Tango

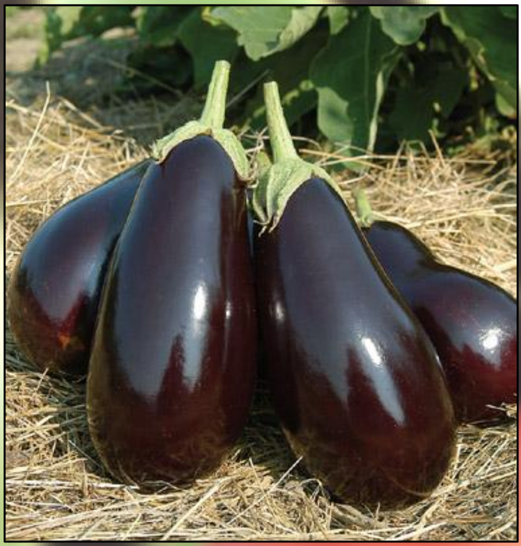
Cucumbers
3 plants
15 lbs produce
14 ($) revenue
3 growing cycles

Corinto



Northern Pickling

Eggplants
3 plants
24 lbs produce
40 ($) revenue
1 growing cycle



Galine

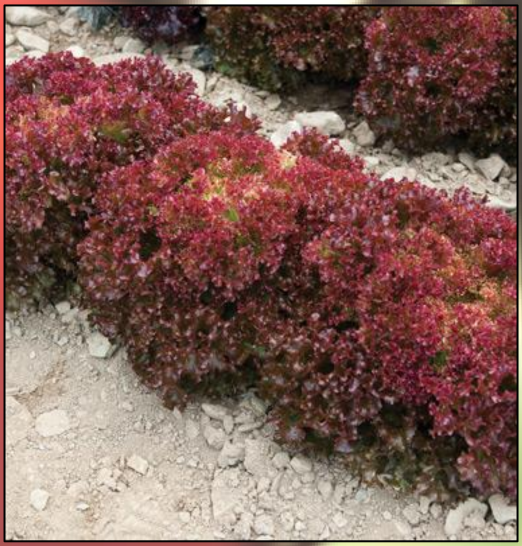
Leeks
20 plants
3 lbs produce
6 ($) revenue
1 growing cycle

Lexton

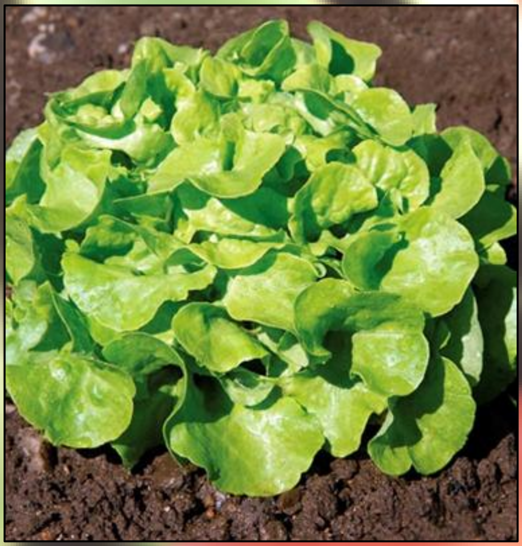
Red Cash

Green Forest

Lettuce
45 plants
50 lbs produce
37 ($) revenue
4 growing cycles



Antonet



Panisse

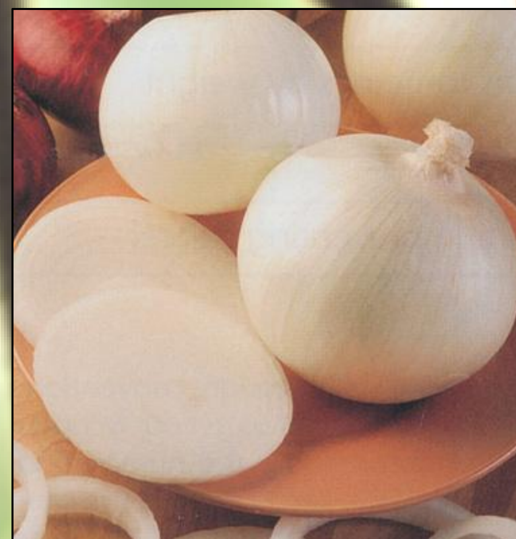
Rex

Onions
60 plants
42 lbs produce
22 ($) revenue
1 growing cycle

Candy

Nabechan

Ruby Red



Sierra Blanca

Peppers
10 plants
20 lbs produce
10 ($) revenue
2 growing cycles

Gourmet

Olympus

Potatoes
5 plants
29 lbs produce
9 ($) revenue
1 growing cycle

Yukon Gold

Dark Red Norland

French Fingerling

Radishes
200 plants
10 lbs produce
7 ($) revenue
5 growing cycles

Rover

Spinach
480 plants
24 lbs produce
47 ($) revenue
7 growing cycles

Space

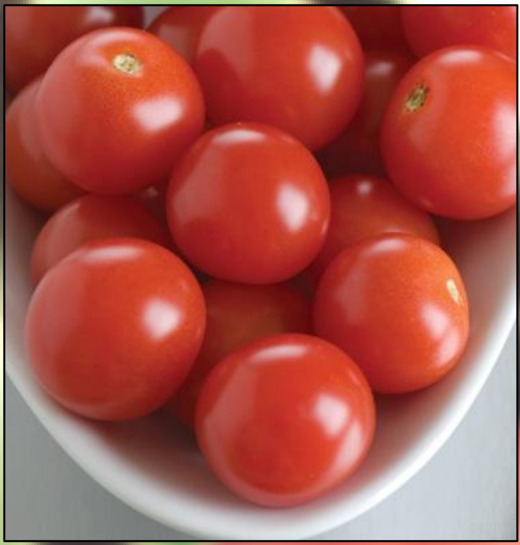
Squashes
1 plant
20 lbs produce
12 ($) revenue
1 growing cycle

Winter Sweet

Waltham Butternut

Tomatoes
10 plants
80 lbs produce
80 ($) revenue
2 growing cycles

Granadero



BHN-968

Rebelski

Striped German

Zucchini
3 plants
24 lbs produce
32 ($) revenue
3 growing cycles

Tigris

Herbs

Rosemary

Common Mint

Common Sage

Calypso

Giant of Italy

Genovese

Financial Autonomy

In the course of our study we developed a financial model based upon units with a floor space of 3600 square feet that could be adapted to either winter or summer growing purposes. This financial model included initial investment in infrastructure, operating costs, maintenance costs, staffing (which includes a full time manager), and revenue. All of these numbers were verified by an Operations Director at Community Harvest Project in North Grafton, and the quality of our models were critiqued by our own Assistant VP of Facilities Alfredo DiMauro. Even while ignoring 50% of our potential revenue and using conservative estimates of all costs and initial expenses, we were able to show that there exist several models that can be built on a 1.5 acre plot or smaller that generate enough profit to pay themselves off in a period of time that ranged from 3 to 15 years.

The arrangement of the corresponding material is as follows:

1. **Financial Models**
2. **Investment and Cost Totals/Staffing**
3. **Investment Cost Tables**
4. **Yearly Expense/Maintenance Cost Tables**
5. **Revenue**

The Financial Models section provides summaries of several financial autonomous models for a WPI farm.
The Investment and Cost Totals/Staffing section summarizes the investment and costs for a single 3600 sq-ft unit and the staffing for 1.5 acre plot.
The Investment Costs Tables contain the numbers from our investment calculations for a single 3600 sq-ft unit.
The Yearly Expense/Maintenance Costs Tables contain the numbers from our yearly expense calculations for a single 3600 sq-ft unit.
Revenue contains the calculations we used in determining a conservative estimate of expected revenue.

Financial Models

The following table outlines several models for a WPI farm. The numbers for each point are for an entire calendar year. For each model we have as the main points: the number of units, the number of units that are winterized (have a greenhouse built on top of the floor area, a heater, and lights), and the payoff time. As supporting points each model has outlined the setup costs (initial investment), the operating costs (including maintenance), the labor cost, the revenue, and (calculated from the previous three) the profit.

1.5 Acres	Units	Winter Units	Payoff Time	Set-up Cost	Operating Cost	Labor Cost	Revenue	Profit
SUMMER 1	5	0	8	83000	9500	33000	53000	10500
SUMMER 2	8	0	4	132800	15200	33000	84800	36600
SUMMER 3	12	0	3	199200	22800	33000	127200	71400
WINTER 1	9	1	17	200700	33100	66000	111200	12100
WINTER 2	10	1	11	217300	35000	66000	121800	20800
WINTER 3	12	1	7	250500	38800	66000	143000	38200
WINTER 4	10	2	13	268600	51000	66000	137600	20600
WINTER 5	12	4	14	404400	86800	66000	190400	37600

Notes on the Models:

- SUMMER 1: this model has the fewest number of units that must be open for the farm to be profitable under the assumption that the farm is only open during the summer.
- WINTER 1: this model has the fewest number of units that must be open for the farm to be profitable under the assumption that the farm has one unit open during the winter.
- WINTER 3, WINTER 5: these models have roughly the maximum number of units that can fit on 1.5 acres.

Greenhouse information taken from: http://www.farmtek.com/farm/supplies/home

Investment and Cost Totals/Staffing

The following tables summarize the initial investment, yearly costs (including maintenance), and revenue for a single unit covering 3600 sq-ft. The first three rows contain information for winterized units (those having a greenhouse covering the floor space, in addition to heating and lights). The last three rows contain the same information for summer only units. All costs were obtained from FarmTek's online store. Note that the revenue is based off of the entire unit being cropped with 'revenue' crops (high yield, high price) with 50% of the produce being ignored.

TOTALS	
Purchase Price Winterized	67900
Full Year Cost	17900
Full Year Revenue	26400
Purchase Price Summer	16600
Summer Cost	1900
Summer Revenue	10560

The following tables contain the numbers concerning employment for a farmed area of 1.5 acres. These numbers were taken from estimates given to us by the Operations Director at the Community Harvest Project. In our models we assumed that a full time manager would always be employed while anything was growing. The first portion of this table concerns their pay (which include benefits). The second portion of the table gives the number of hours worked (besides that of the farm manager) for either a full year operation or a summer only operation and the pay corresponding to those hours. The concluding two lines give the total cost in terms of staffing for a single year. (Note that there is no assumption here that any volunteers will be present. Any such volunteers would simply reduce the costs below).

Employment for 1.5 Acres	
FARM MANAGER (INCLUDING BENEFITS)	
Full Year	63000
Summer Only	31500
ADDITIONAL LABOR	
Wage per Hour	10
Full Year (300 hrs)	3000
Summer Only (150 hrs)	1500
TOTAL (FULL YEAR)	66000
TOTAL (SUMMER ONLY)	33000

Labor data supplied by Ken Dion, Operations Dir., Community Harvest, N.Grafton.
Greenhouse information taken from: http://www.farmtek.com/farm/supplies/home

Investment Cost Tables

Greenhouse Unit Cost		
TOTAL PRICE (WINTERIZED)		**67924**
TOTAL PRICE (SUMMER ONLY)		**16622**

DIMENSIONS		
Length (ft)	Width (ft)	**Area (sq-ft)**
120	30	**3600**

UNIT COST	
Cost of 60'x30' Section	20899
Cost of Greenhouse End	2225
Number of Each	2
Total	**46248**

LIGHTING	
Lumens per Unit	130000
Required Lumens per sq-ft	900
Number of Units	**25**
Cost per Fixture	110
Cost per Bulb	43
Total	**3825**

FANS	
CFM per Unit	3300
Required cfm per sq-ft	8
Number of Units	**9**
Cost per Unit	150
Total	**1350**

FANS	
CFM per Unit	3300
Required cfm per sq-ft	8
Number of Units	**9**
Cost per Unit	150
Total	**1350**

HEATING	
BTU per Unit (at 80%)	160000
Required BTU in Coldest Month	130000
Number of Units	**1**
Cost per Unit	1229
Total	**1229**

IRRIGATION	
Price of 3 hp Water Pump	1475
Cost of 2050' Drip Tape	81
Cost for 333' of Tubing	21
Price for Adaptors, etc.	20
Total	**1597**

RAISED BEDS	
Number of Units	**5**
Cost per Unit	2735
Total	**13675**

TOTAL PRICE (WINTERIZED)	**67924**
TOTAL PRICE (SUMMER ONLY)	**16622**

CFM information/Water:
http://ag.umass.edu/fact-sheets/design-layout-of-small-commercial-greenhouse-operation
Irrigation equipment parameters suggested by Ken Dion, Community Harvest, N.Grafton.
Irrigation equipment vendor and prices:http://www.rainfloirrigation.com

Investment Cost Tables

Raised Bed Unit Cost			
TOTAL COST			**2735**
DIMENSIONS			
Perimeter Length (ft)		**208**	
Length (ft)	Width (ft)		
100	4		
Height (ft)		**3**	
Volume (cubic yards)		**44**	
LUMBER ESTIMATE			
Lumber Width (ft)			1
Lumber Length (ft)			8
Pieces Required			**78**
COST PER RAISED BED			
Price per Piece			**13.97**
Cost for Pieces			1090
Cost Set Aside for Other Materials			545
Soil Cost per cubic yard			**25**
Cost for Soil			1100
Total			2735
TOTAL COST			**2735**

Lumber vendor HomeDepot:
homedepot.com/p/WeatherShield-2-in-x-12-in-x-8-ft-2-Pressure-Treated-Lumber-255974/100022372
Soil vendor and prices: mass http://massachusettsmulchdelivery.com

Yearly Expence/Maintenance Cost Tables

This section is composed of the following tables:

1. Heating
2. Water
3. Electricity
4. Fertilizer
5. Irrigation
6. Equipment Replacement Costs

Heating:
The following numbers are based off of the material properties of the greenhouse unit detailed in the facility section of this document and the recorded weather in Worcester, MA: https://weather.com.

Heating			
AVE. COST PER HEATED MONTH			**1297.97**
Surface Area (sq-ft)			5765
Material	6mm Twinwall Polycarbonate		
Price per Gallon of Propane			2.3
Internal Greenhouse Temperature (F)			80
HEATING PER MONTH			
Month	**Avg. Low (F)**	**Gallons of Prop.**	**Cost**
Jan	25	783	1800.9
Feb	30	712	1637.6
Mar	35	640	1472
Apr	40	569	1308.7
May	55	356	818.8
Jun	0	0	0
Jul	0	0	0
Aug	0	0	0
Sep	55	356	818.8
Oct	50	427	982.1
Nov	40	596	1370.8
Dec	35	640	1472
AVE. COST PER HEATED MONTH			**1297.97**

Climate data and calculation made with www.littlegreenhouse.com/heat-calc.shtml

Yearly Expence/Maintenance Cost Tables

Water:
Given the unpredictable nature of water consumption, we based our numbers off of commercial lettuce growers in Arizona in order to give a conservative estimate for our study.

Water	
COST PER MONTH	**34.07**
BASIS	
Based on Lettuce Growers in Arizona	
CONSUMPTION	
Consumption (gal/sq-ft/y)	23.66
Area (sq-ft)	3600
Consumption per Month	**7098**
WATER COST	
Price per Gallon	0.0048
COST PER MONTH	**34.07**

Water requirements: ncbi.nlm.nih.gov/pmc/articles/PMC4483736/

Yearly Expense/Maintenance Cost Tables

Electricity:
In calculating our electricity cost we considered the pumping of water, fans, and for winterized units, heating and lighting. For lighting and fans, data on power consumption was taken from FarmTek's online store. For the water pump power consumption was taken from waterpumpsupply.com: http://store.waterpumpsupply.com/bepu5hp1ph36.html

Electricity	
COST PER MONTH (WINTER)	**502.97**
COST PER MONTH (SUMMER)	**115.52**
Cost per kWh	0.0738
Mega Joules per kWh	3.6
LIGHTING	
ASSUMPTIONS	
25 1000W High Pressure Sodium Bulbs	
7 Hours Supplemented Lighting in Winter	
COSTS	
Consumption per Month (MJ)	18900
Total Cost per Month	**387.45**
FANS	
ASSUMPTIONS	
9 230W Fans	
24/7 Operation	
COSTS	
Consumption per Month	5365
Total Cost per Month	109.98

WATER PUMP	
ASSUMPTIONS	
1 5000W (Full Capacity) Pump	
30min/day Operation	
COSTS	
Consumption per Month (MJ)	270
Total Cost per Month	**5.54**
TOTAL COST	
COST PER MONTH (WINTER)	**502.97**
COST PER MONTH (SUMMER)	**115.52**

Condition requirements: ncbi.nlm.nih.gov/pmc/articles/PMC4483736/
Equipment vendor and prices: http://www.farmtek.com/farm/supplies/home

Yearly Expense/Maintenance Cost Tables

Fertilizer:

The following table contains the amount of fertilizer that is needed per application in a single 3600 sq-ft unit, the cost of such fertilizer, the number of applications required per year (for a single unit), and finally the total cost per unit per year (note we do not distinguish between summer and winter units here: this only leads to a conservative estimate for the summer units).

FERTILIZER	
TOTAL COST	**200**
APPLICATION	
Nitrogen, lb/acre	100
Phosphorus, lb/acre	75
Potassium, lb/acre	125
Applications per Year	**8**
COSTS	
Price per pound	0.9
Area of application, sq-ft	3600
Price per application	25
TOTAL COST	**200**

Irrigation:

The following table outlines the maintenance costs for the irrigation system in a single 3600 sq-ft unit.

IRRIGATION	
TOTAL COST	**122**
COSTS	
Cost of 2050' Drip Tape	81
Cost for 333' of Tubing	21
Price for Adaptors, etc.	20
TOTAL COST	**122**

Irrigation equipment parameters suggested by Ken Dion, Operations Dir., Community Harvest, N.Grafton.
Irrigation equipment vendor and prices:http://www.rainfloirrigation.com
Fertilizer:
http://www.extension.umn.edu/garden/fruit-vegetable/nutrient-management-for-commercial-fruit-and-vegetables-in-mn/docs/5886_full.pdf and http://www.noble.org/ag/soils/nitrogen-fertilizer-worth-cost/

Yearly Expense/Maintenance Cost Tables

Equipment Replacement Costs:
These tables outline the equipment lifetimes, equipment unit costs, and therefore the portion of these costs that must be supplied each year. Finally, the table concludes with the final cost: the sum of all of those portions.

EQUIPMENT LIFETIMES	
High Pressure Sodium Lamp	13
Lamp Fixture	15
Fan	7.5
Heater	10
Water Pump	15
COSTS	
High Pressure Sodium Lamps	1075
Lamp Fixtures	2750
Fans	1350
Heater	1229
Water Pump	1475
REPLACEMENT COSTS PER YEAR	
High Pressure Sodium Lamps	82.69
Lamp Fixtures	183.33
Fans	180
Heater	122.9
Water Pump	98.33
TOTAL COST	**667.25**

Equipment information taken from: http://www.farmtek.com/farm/supplies/home
Fan lifetime: http://orionfans.com/how-to-read-a-data-sheet/life-expectancy.html
Sodium lamp lifetime:
http://gro-kart.com/blog/2015/01/everything-you-ever-wanted-to-know-about-high-pressure-sodium-grow-lights/
Water pump lifetime: http://inspectapedia.com/water/Well_Pump_Life.php

Revenue

The following calculations gave us the numbers that were used in determining the likely revenue that a single unit could generate over the course of a year. For simplicity, we used a unit stocked with Tomatoes only, but given crops with similar value (in terms of yield and price) one would arrive at similar numbers for a variety of crops grown. The price per pound of tomatoes was taken from the USDA and the yield was taken from consideration of the hobbyist sources given in the variety section. Of important note, we have considered the case where only 50% of our produce is actually sold. This leads to a very conservative estimate for revenue that allows a lot of room for crop failure, more variegated planting, and experimenting with new growing techniques.

EXAMPLE REVENUE	
FULL YEAR	**26400**
SUMMER ONLY	**10560**
ASSUMPTIONS	
Revenue Generated by Profit Crops Like Tomatoes and Spinach	
The Following Numbers Assume the Entire Crop (of a Greenhouse) is Comprised of Profit Crops. (This allows for easy rescaling)	
TOMATO PLANT QUANTITY	
Inter Plant Spacing (ft)	1.5
Width of Raised Bed (ft)	4
Plants per Width	2
Plants per 100' Raised Bed	132
Number of Raised Beds	5
Total Number of Plants	**660**

TOMATO PLANT YIELD	
Avg. Pounds per Plant	8
Total Pounds per Plant Life-Cycle	**5280**
REVENUE PER LIFE-CYCLE	
Price per Pound Tomatoes	2
Percentage Sold	0.5
Revenue per Life-Cycle	**5280**
Life-Cycle Length (days)	70
FULL YEAR REVENUE	
Number of Cycles	5
Total Revenue	**26400**
SUMMER ONLY REVENUE	
Number of Cycles	2
Total Revenue	**10560**

Prices of produce taken from http://www.ers.usda.gov/data-products/fruit-and-vegetable-prices.aspx
Average yields taken from http://www.johnnyseeds.com and various hobbyist cites.

WPI Interest

During the course of our study we interviewed several people representing a wide range of types at WPI: faculty, students, administration, and facilities. In each of these areas we found interest in the concept of a WPI farm as a valuable asset to WPI, both in terms of education and in terms of WPI's impact on the local Worcester community. We were able to verify that there would be substantial use of this farm by WPI and that several departments and branches of WPI would be interested in becoming involved with and taking advantage of such an operation. The following pages outline the types of interest found throughout our study.

The pages following divide as follows:

1. **Faculty, Facilities, and Administration**
2. **Students**

For the actual notes on interviews from which this data was gathered, refer to the appendices.

Faculty, Facilities, and Administration

Interviewed During the Course of Our Study:

1. **Professor Kristin Wobbe**
2. **Professor Elisabeth Stoddard**
3. **Professor Suzanne LePage**
4. **Professor Patricia Stapleton**
5. **Professor John Orr**
6. **Alfredo DiMauro**
7. **Alen Carlsen**
8. **Linda Looft**

During the course of our study we found a diverse set of interests that are manifest in individuals from each of the areas of faculty, facilities, and administration.

In terms of faculty there was a broad range of academic interests. Most of these are outlined in the Projects section of this report but we will outline a few included there and those not included there here for demonstration of these diverse interests:

Project Work

- Greenhouse Designs
- Market Analysis
- Distribution Models/Projects
- Trying/Demonstrating Better Farming Practices
- Gompei's Goat Cheese
- MA Ag Policy Analysis
- Chem Eng Projects
- Ethics in what You Raise
- Composting
- Runoff
- Creating More Tolerant Species
- GPS

In addition to this, several of the faculty interviewed expressed interest in the community outreach that could be done through such a farm including summer programs for middle schoolers, summer employment for high schoolers, distribution of food to food deserts, city beautification, coordination with Worcester's Food Hub, and, in general, development of sustainable agriculture practices useful right here in Worcester.

In summary, a WPI farm would have interested faculty from Social Science and Policy Studies, and the Chemistry and Biochemistry Department.

Faculty, Facilities, and Administration

In terms of facilities, there was interest shown in the idea of growing the annuals and perennials used by WPI in one of the farm's units. This project would have the potential to save a considerable amount of money. But a full cost and risk analysis would have to be done before such benefits could be certain. Beyond that, in our conversation with the facilities side of WPI we gathered that our model design was solid and certainly doable given the appropriate initial investment and partners.

In speaking with administration at WPI, it became clear to us that this would be a meaningful project for WPI, especially in the sense of how much city value could be added with such a farm. Therefore it would only strengthen the relationship between the city and WPI, and allow for many more meaningful and interesting projects here within the city.

Students

During the study we interviewed six students. These students came from a list of 30 students randomly selected from a list of students participating (or once participant) in groups or classes that would suggest interest in a WPI farm. We were able to show that our random sample (from a list of 160 students) all had exceptional interest in the idea of a WPI farm. This would suggest to us that we have a more than sufficient amount of student interest to justify a WPI farm. The details of our results follows.

Of the six students interviewed, each one said that they would be interested in a WPI farm. In addition, each of the six answered that they would like to see a WPI farm primarily run by students and would be willing to volunteer at least 1-3 hours of their time per week in working at the farm. As such there is potential for much of the farm labor and management to come from students working as volunteers. Barring this, all students interviewed said that they thought Work-Study at the farm would be interesting to at least some of the students participating in such programs.

In terms of academic programs and projects, students all agreed that classes could use the farm should if it were to exist. In addition, a few project ideas were proposed by a couple of the students including:

- Rain Water Catchment
- Composting
- GMO design
- Organic Techniques

Finally, all students answered that they would like to buy produce from the farm, two saying they would do so occasionally, and four stating that they would regularly buy produce if it was available. Of the produce that they mentioned as interesting to them, we have a sample:

- Spinach
- Peppers
- Cucumbers
- Tomatoes
- Squash
- Greens
- 'Unusual' Produce
- Strawberries

In conclusion then, we were able to verify that for our sample of students there is definite interest in a WPI farm both academically and in terms of its ability to produce food of interest to students. In addition we found that students were not only interested in seeing major student involvement in such a project, but are also willing to volunteer their time in order to be part of it. As a final note, for the size operation we are considering, the hours of labor needed besides the farm manager per week amounts to roughly five. Therefore, with these six students alone we have demonstrated a larger potential labor force than the one we necessarily need.

Markets

Farm can create tons of fresh fruits and vegetables. Our research has brought us to two results in terms of selling and distributing the produce. The first one is Lettuce Be Local and the second is Chartwells. Chartwells gets their produce through a few distributors and Lettuce Be Local distributes the produce. Our calculations for this study is on the assumption that only 50% of the produce made will be sold. The other 50% of it will either be donated to food banks, shelters, or brought to food desert areas.

The sections will proceed in the follow the order of:

1. **Lettuce Be Local**
2. **Chartwells**

Lettuce Be Local

We had a short phone conversation with Lynn from of Lettuce Be Local. When telling her about the possible size of a WPI farm, she told us that there would be a soil test before anything gets distributed, but other than that there will be no problem distributing everything that the farm produces.

Chartwells

We had a meeting with Joe Kraskouskas from Chartwells and he was able to supply some numbers on the amount that the Campus Center uses per week as well as a few numbers from Pulse On Dining. In one week the Campus Center and Pulse on Dining both use around 500 pounds of tomatoes. If a WPI farm only produces tomatoes, around 5000 pounds would be produced in 11 weeks. If we wanted to sell to Chartwells, then we would have to go through one of their distributors.

In conclusion there is no problem when it comes to distributing all of the produce that a farm will make.

Projects

A farm environment is complex. On the one hand, the farm is a physical structure; it provides a durable shelter for plants, necessary infrastructure to supply water, heat, light etc. On the other hand, the farm has to accommodate a fine biological system in a way that ensures control and flexibility. Yet, from a different point of view, a farm in a dynamic enterprise. The produce grown at the farm needs to be distributed to its consumers. In summary, a farm provides an exceptional platform for a variety of projects, from the most technical engineering research such as developing sensors, irrigation systems, automation technologies, to social and humanitarian endeavors such as food distribution and nourishment research, to business-oriented hands-on work in management.

To determine the interest of WPI Students and Faculty in farm-related projects, we have interviewed professors Elizabeth Stoddard, Patricia Stapleton, John Orr and Kristin Wobbe, and seven WPI undergraduate students. Below, as suggested by the respondents, is list of "interesting" projects and topics suggested by the respondents that can be completed at the WPI farm:

- Greenhouse Designs
- Market Analysis
- Distribution Models
- Demonstration of Improved Farming Practices
- Massachusetts Agricultural Policy Analysis
- Projects in Chemical Engineering
- Soil Composition Analysis
- Irrigation and Nutrient Supply
- Ethics in what You Raise
- Composting
- Runoff
- Creating More Tolerant Species
- Great Problem Seminars

This list of project demonstrates the potential of a WPI farm to contribute to WPI project-based curriculum and WPI mission to serve the community of Worcester.

City Interest

There are 4 key points in how The city of Worcester can benefit from a WPI Farm

1. **There are areas within Worcester in which a store selling fresh food is hard to find, and serious effort has to be made to travel to a location where such a store can be found. These areas are more commonly known as food deserts. A farm can supply fresh, local, affordable produce to these areas**
2. **Worcester has a desire to promote local food: its production, marketing, and distribution. Central to pursuing this vision are organizations and initiatives such as Worcester FoodHub and Regional Environmental Council. A WPI farm can join the local effort to provide service to the city.**
3. **The changing nature of Worcester's demographics requires access to fresh and diverse produce. With the steady stream of refugees and immigrants, Worcester is becoming more diverse and, as a result, has a need to adapt to the desires and markets that come with the new cultures and peoples within the city. A farm can provide this access.**
4. **Worcester is still transitioning out of America's industrial era with large pieces of land being unutilized or underutilized. A WPI farm can ameliorate the landscape of the city replacing the crumbling relics of that previous era.**

In summary, these 4 key points show the possible impact that a WPI farm can have. Through bringing outreach ideas into practice, by leading the way for local production, by nurturing Worcester's emerging demographic, and by enlivening and beautifying the city, a WPI farm would bring powerful benefits to its host city, Worcester.