EPICS / PURDUE

Urban Farming

Team Members

Alyssa McNarney	Chemical Engineering	*Project Manager*
Madeline Moisio	Humanitarian Engineering	*CSA Design Lead*
Ethan Edwards	Civil Engineering	*Prototype Design Lead*
Aaron Nunes	Civil Engineering	*Finance Design Lead*
Brandon Banks	Electrical Engineering	*Project Partner Liaison*
Laurel Norris	First Year Engineering	*Financial Officer*
Natalie Zamiechowski	Chemical Engineering	*Webmaster*
Troy Weber	Environmental and Ecological Engineering	
Joyce Bernardino	First Year Engineering	
Daniel Eshleman	First Year Engineering	
Diana Del Real	First Year Engineering	

Agenda

Framing the issues

Project Details

Questions and Comments

Framing the Issue: Food Deserts

Underserved by Quality Grocery Stores

- Distance to store is >1 mile in urban areas and >10 miles for rural areas
- Disproportionately in low income communities
  - 55% found in communities with median income less than $25,000 per year

Limited Options for Food

- Reliable access to high calorie, processed unhealthy food
- Creates poor diets and health effects
  - High blood pressure, diabetes, heart disease, etc

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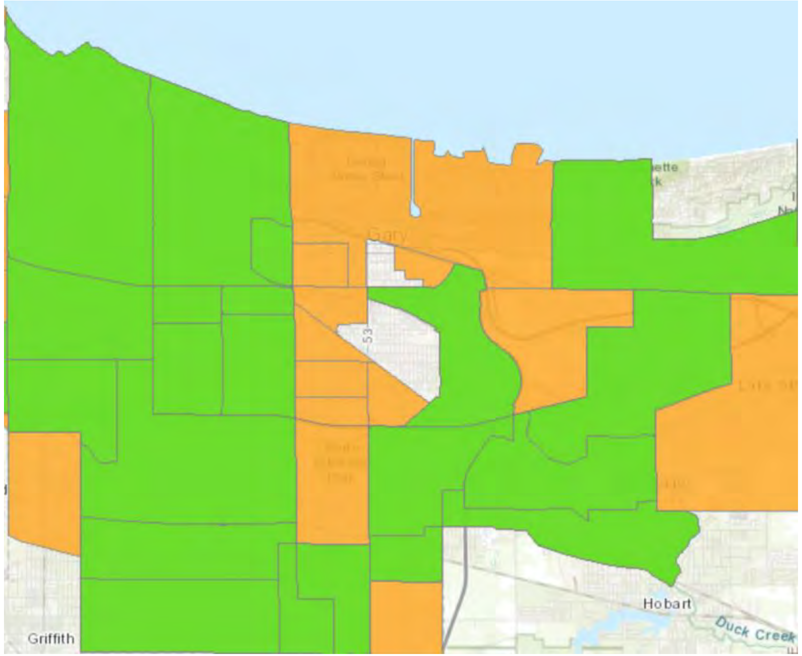
Framing the Issue

Gary, Indiana



Orange = ½ mile from nearest grocery store

Green = 1 mile from nearest grocery store

https://www.nwitimes.com/business/map-food-deserts-in-northwest-indiana/html_6ec49482-ce22-57fc-9d04-2f8c286b3ea0.html

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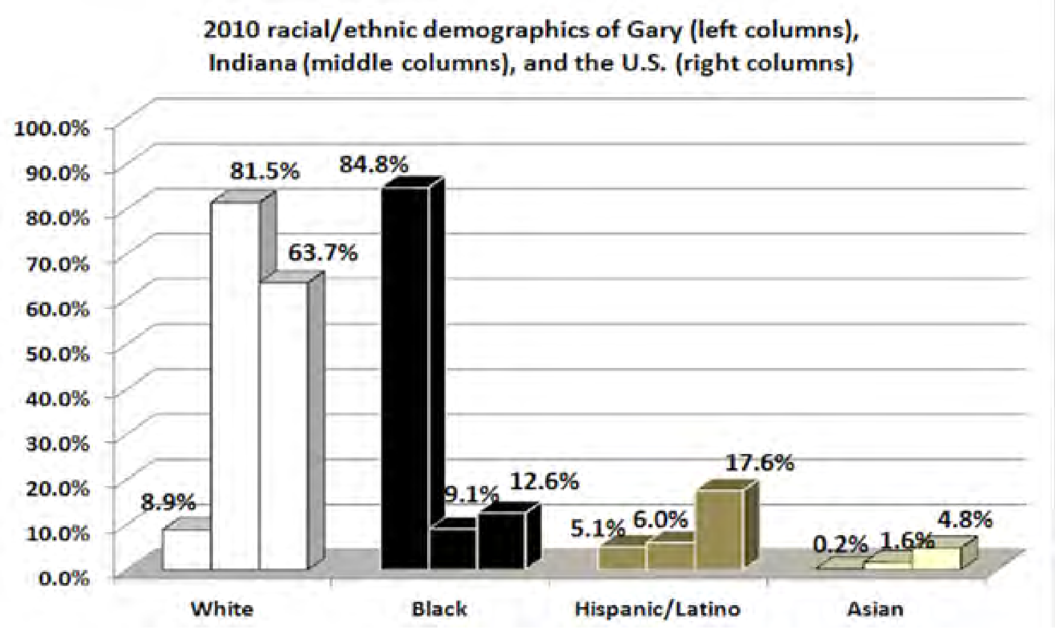
Framing the Issue: Gary, Indiana

- Majority of population: African American
- Average annual income: $16,000



https://www.census.gov/quickfacts/fact/table/garycityindiana/PST040218#PST040218

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Framing the Issue: Access to Grocery Stores

BARRIERS

Ability	Location
Availability	Reliability
Child Care	Safety
Cost	Time
Health	Transportation

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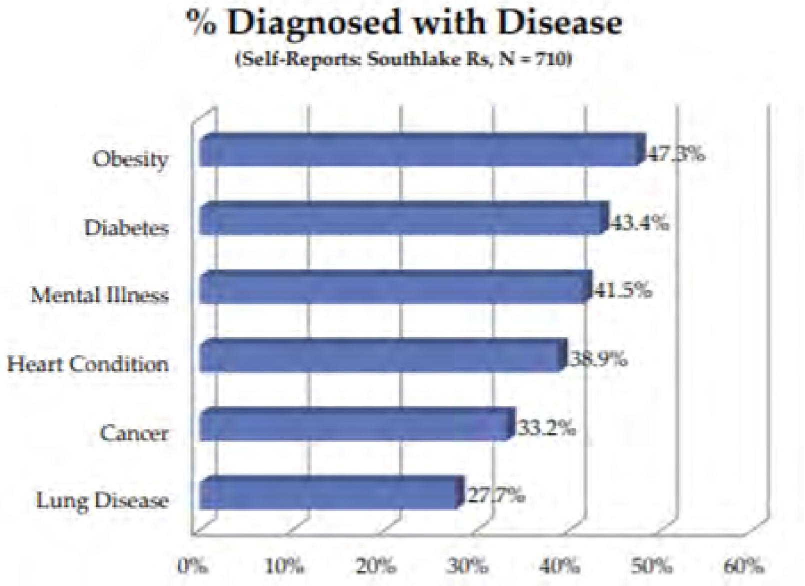
Framing the Issue

Top Self-Reported Health Concerns



"% Diagnosed with Disease" 2016.2016 Survey of the Community. Methodist Hospitals, Southlake Campus. Pg. 21

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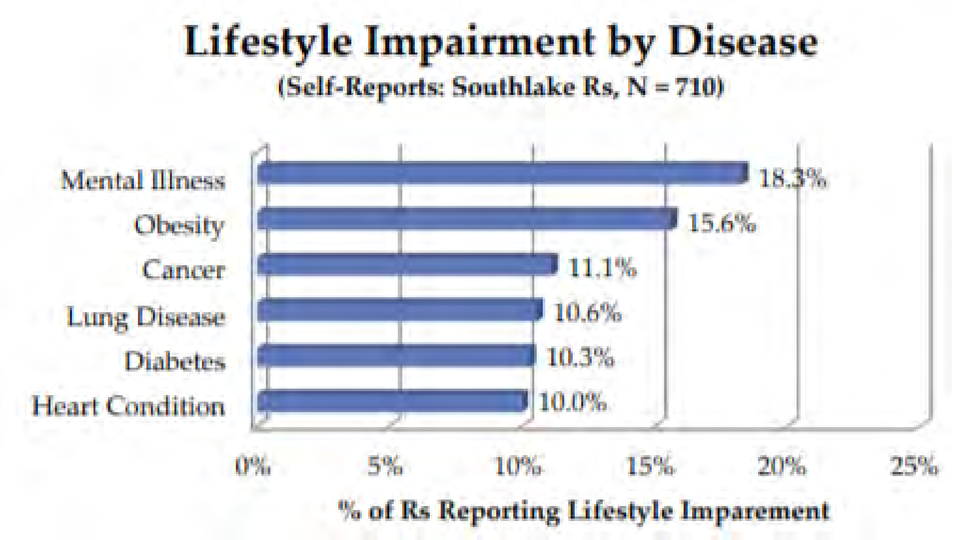
Framing the Issue

Effects of Health Concerns



“Lifestyle Impairment by Disease” 2016. 2016 Survey of the Community. Methodist Hospitals, Southlake Campus. Pg. 21

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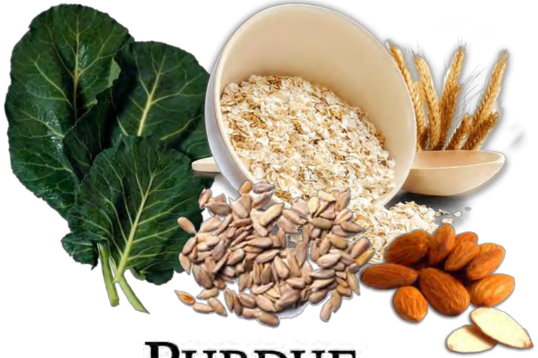
Framing the Issue

Diet Choices that Affect Health Issues

- Diets high in cholesterol lead to many of the previously stated health issues
- Optional diet changes:
  - Foods low in trans fats, saturated fats, and sodium
  - Whole grains
  - Leafy greens
  - Nuts and seeds
  - Limit red meat consumption



Vieira, G. (2019, July 30). Type 2 Diabetes and Plant-Based Diets. Retrieved from https://www.healthline.com/health-news/the-right-plant-based-diet-can-lower-your-risk-for-type-2-diabetes.

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Scope of Project

EPICS

- Aquaponics
- Rooftop Garden
- Solar Panels
- Community Supported Agriculture

Stakeholder

- Convenience Stores
- Agriculture Fair
- Food Delivery
- Restaurant “Sunday Dinner”

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4 Year Project Timeline

2019 | 2020 | 2021 | 2022

- Aquaponics system and installation
- Building drawings and building reinforcement
- Community supported agriculture, grants, and motorpool updates
- Solar panels design and installation
- Rooftop garden and installations
- Delivery details and revisions

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Where EPICS Can Help

Our goal is to build infrastructure to produce food that is both beneficial and accessible to those in need in Gary, Indiana.

EPICS®

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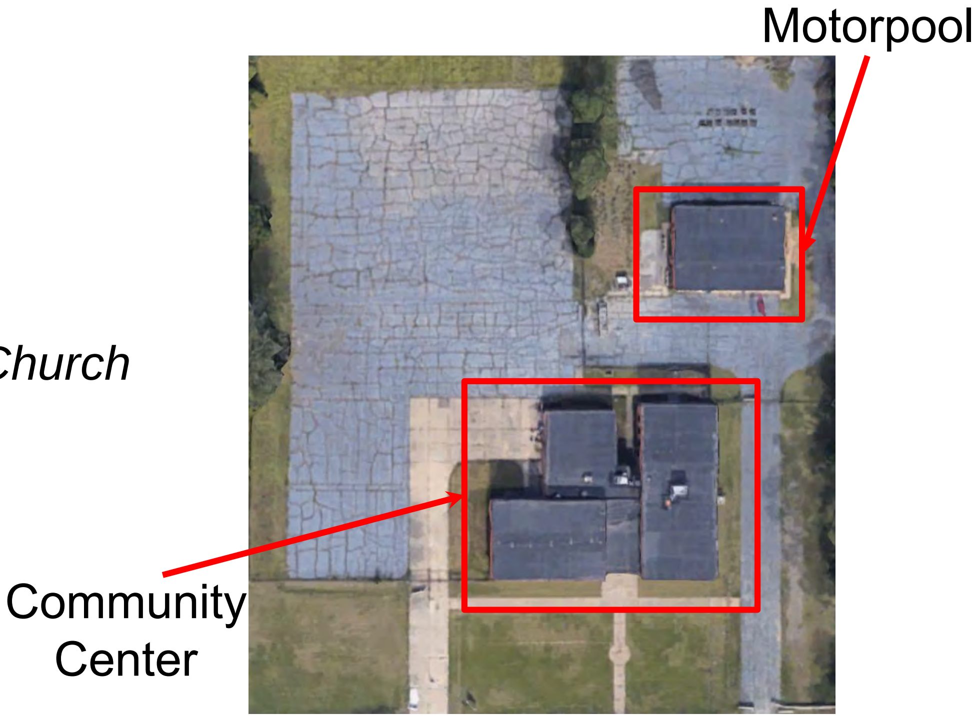
Stakeholders

Project Partner

Marty Henderson
Peace Gardens & Farms
Master Gardener
Senior Pastor – *Peace Baptist Church*

4 workers
6.2 acres of land
Provides food for 85 families



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Stakeholders

- Gary Youth
- Members of community
  - Healthier food provided
- Re-entry of justice served individuals
  - Work 1
- Local grocery stores

Project Details

Problem Statement

Our goal for this semester was to finish constructing the aquaponics prototype and establish key learnings for it, develop a community supported agriculture (CSA) plan, and perform cost analysis on the project.

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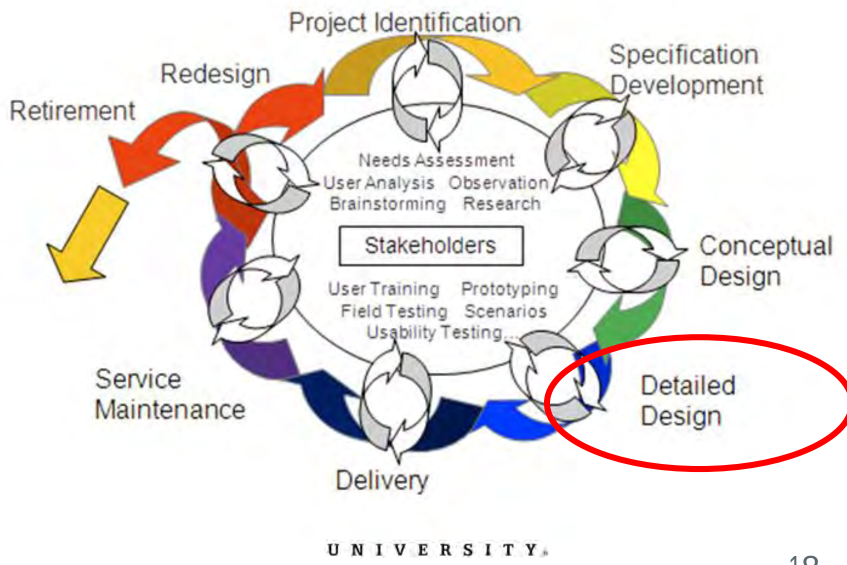
EPICS Design Phase

Detailed Design Phase:

Goal is to design working prototype which meets functional specifications.

- Thought through several possible solutions
- Currently making the aquaponics prototype for our project
- Got feedback from stakeholders
- Field testing will happen once our prototype is tested here



Summary of Last Semester

Spring 2019

- Made a decision matrix for garden type
- Started getting things together for our prototype
- Make long term timelines and goals for the team
- Worked on brainstorming ideas for a mobile market
- Created CAD designs for the prototype
- Started a plan for implementing into the motor pool
- Started to work on permits and procedures for the system
- Went on a site visit to gather information for the project

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Site Visit Takeaways

September 28th

- Metric of food: 40 lbs of produce per family per year (family = 4 people)
- Growing year round in hoop houses
- Measurements of our growing area
- Top 4 vegetables people want
- Plans for the whole property

Site Visit Takeaways

East Chicago Aquaponics

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Community Supported Agriculture

Definitions

What is a CSA?

- Community Supported Agriculture

https://www.nal.usda.gov/afsic/community-supported-agriculture

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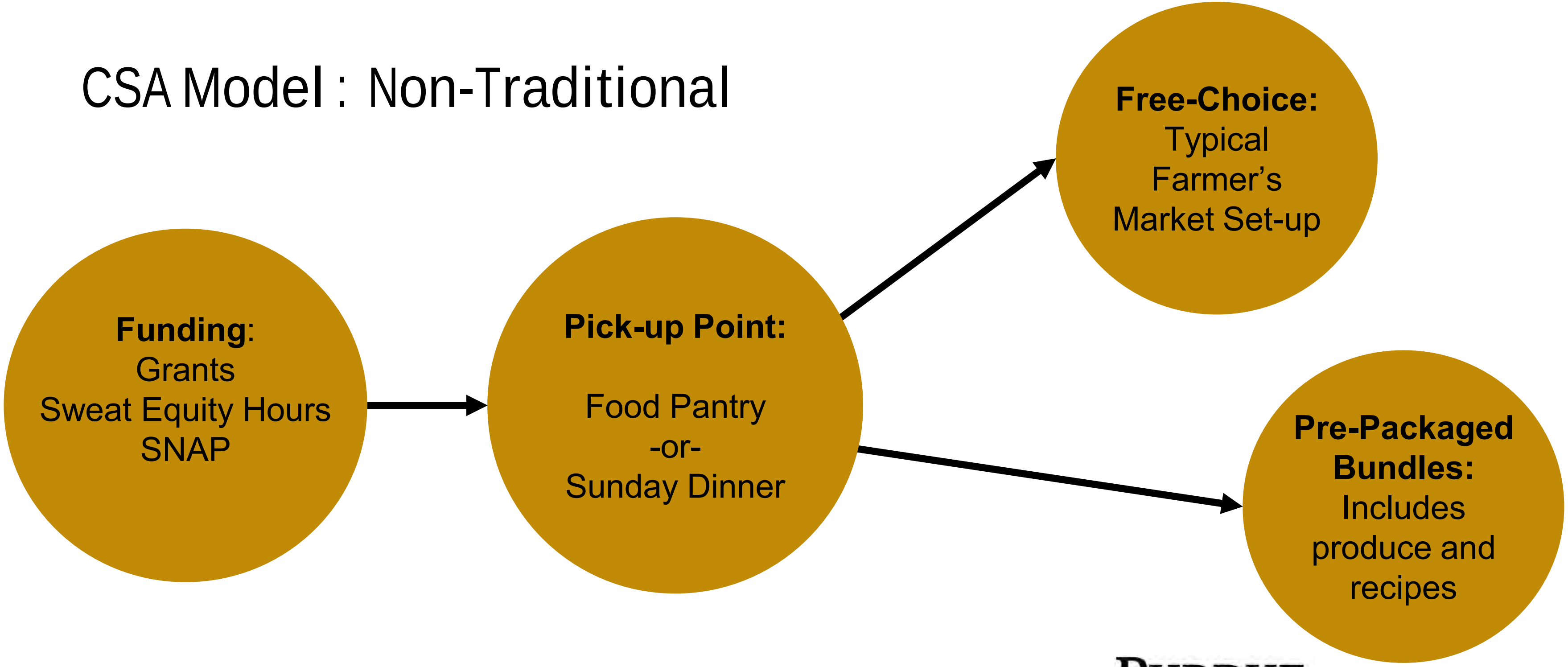
Definitions

CSA Model : Non-Traditional



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Project Phases

1. Produce

What is being grown, where, and when will it be available?

2. Packages

What resources are included with the package, how does the user interact with them?

3. Procedures

What is the process for harvesting, cleaning, sanitizing, storing, and delivering produce?

4. Delivery

How is the program advertised? What channels are used for communication?

5. Impact

What are the outputs and outcomes of the program? What is the next iteration?

Ongoing: Funding

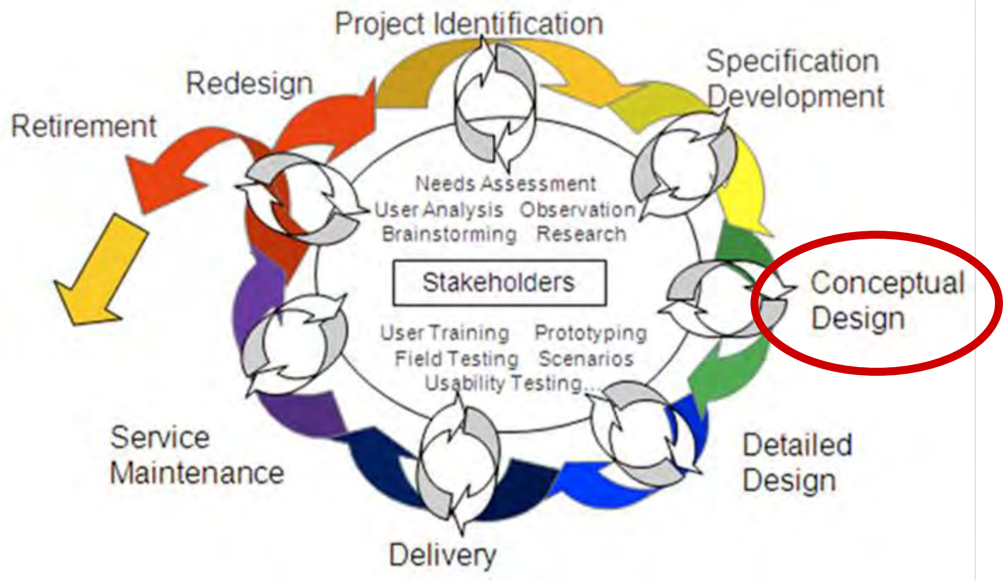
What are grants looking for? How are we funding this program?

Phases in the Design Process

Fall 2019

Phase 1: Produce

Phase 2: Packag



Phases in the Design Process

Fall 2019

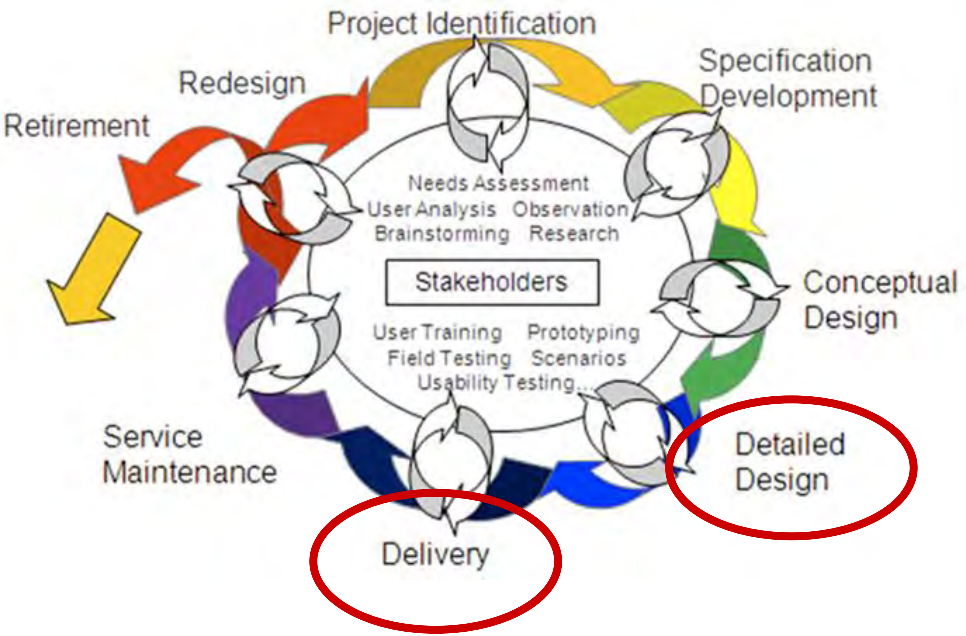
Phase 1: Produce

Phase 2: Packag

Spring 2020

Phase 2: Packag

Phase 3: Procedures
Phase 4: Deliver
Phase 5: Impact



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Fall 2019 Semester Deliverables

Phase 1: Produce

1. Farm Plan and Algorithm *(Senior Design Project)*
2. Harvesting + Storing Profiles

Phase 2: Packages

1. Health-Conscious Recipes
2. Handouts for Packages: *Recipe, Storage, Health Benefits*

Ongoing: Grants

1. Logic Model for Meeting with Franciscan Health
2. Grant Template

Harvest and Storage Profiles

Vegetable	Harvest Season	Storage Time	Short Term Storage	Long Term Storage	Nutrition Facts
Basil	Year Round	3-10 days *(wet)* 3 years *(dry)*	Store in bag with wet paper towel at 50-65 degrees, if they have a stem, trim the stem and place upright in a glass of water and store in cool place	Can be stored in freezer or dried	Low in calories
Beets	March-July	7-8 days	Store in bag with wet paper towel, put in fridge and use in 7-8 days	Frozen, pickled, dried, canned	Low in cholesterol, no fat
Broccoli	August-November	5-6 days	Store in bag with wet paper towel, put in fridge and use in 5-6 days	Can be frozen for 3-4 months	No cholesterol, low in fat, high in fiber
Cabbage	March-July	5-6 or 2-3 days *(depending on storage technique)*	Remove outer, compacted leaves and store in fridge in 5-6 days, place chopped raw cabbage in water and store for 2-3 days in fridge	Can be stored in cold room, root cellar or in garbage bins, do not store long term inside or with other food items, the smell will permeate	Low in cholesterol, calories and fat

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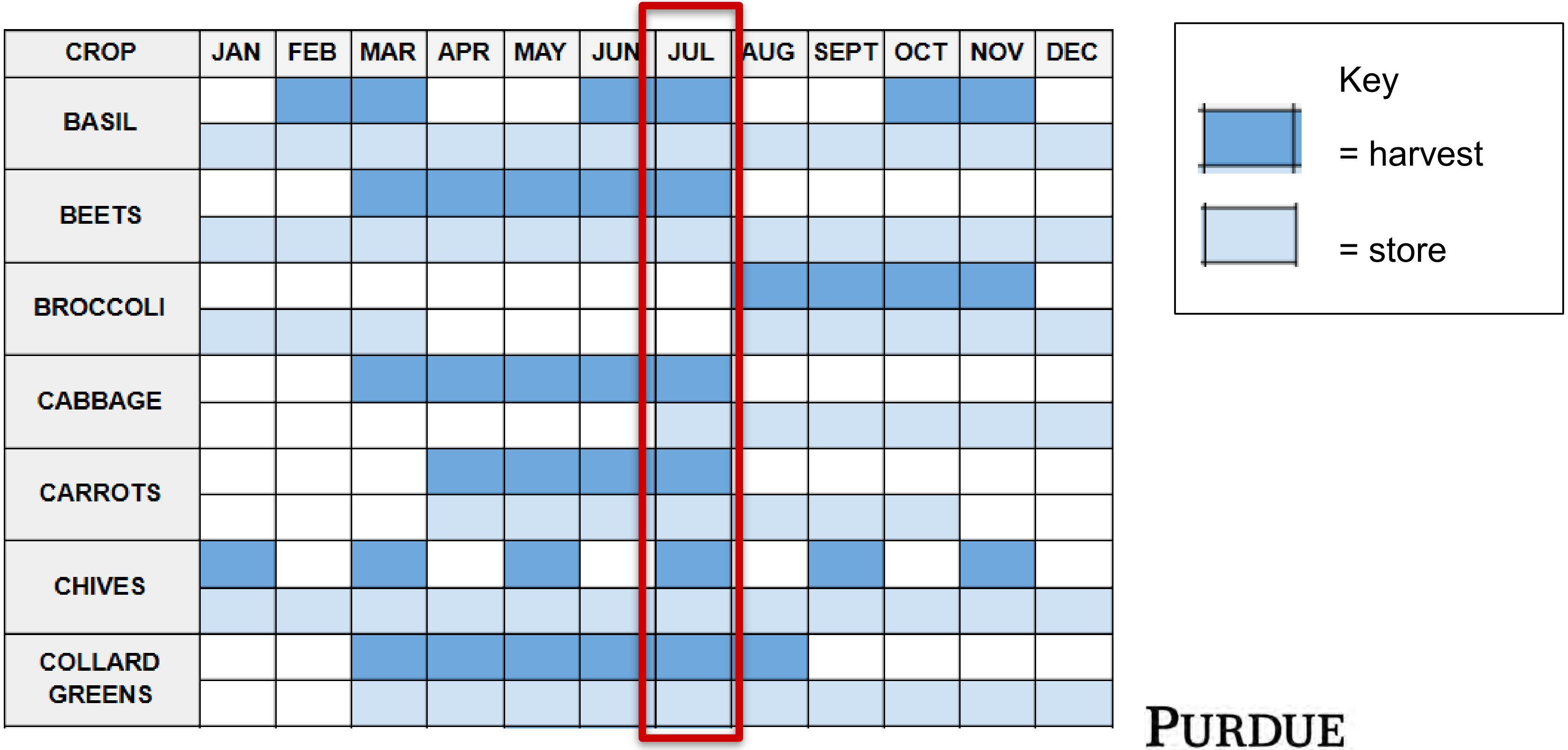
https://www.wikihow.com/Freeze-Beets

Harvesting Schedule



Potential July Package

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Potential July Package

Smothered Greens
& Chicken Gumbo

uses plenty of vegetables and chicken breast!
(which is lower in fat content than the thigh or leg)

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Potential July Package

Produce:	**Storage:**
carrots	place in a plastic bag with a damp paper towel for up to two weeks | store in cool, damp room and pack with damp towels, use within a few months | can be canned, pickled, dried, fermented or frozen
collard greens	can be stored in the fridge for 5 days | can be frozen for 4-6 months
hot pepper	can be stored on the countertop or crisper for 5 days | can be dried or frozen
kale	can be stored on the countertop or crisper for 5 days | can be dried or frozen
okra	store in the warmest part of fridge in a loose perforated bag, use in 3-4 days | can be canned, frozen or pickled
onions	store in a cool place can also be canned, pickled or dried

Health Watch: Heart Health | Low Fat | High Blood Pressure

Side Dish: Smothered Greens

This assortment of vegetables is flavored with turkey stock and is also a classic soul food!

Makes 8 Servings -- *1 Serving = 3/4 cups*

Calories: 165
Saturated Fat: 1 g
Sodium: 81 mg
Protein: 21 g
Potassium: 249 mg

Total Fat: 4 g
Cholesterol: 51 mg
Total Fiber: 2 g
Carbohydrates: 11 g

Main Dish: Chicken Gumbo

This adapted Chicken Gumbo recipe is chock full of vegetables and uses chicken breast, which is less fatty than the leg or thigh!

Makes 8 Servings -- *1 Serving = 3/4 cups*

Calories: 165
Saturated Fat: 1 g
Sodium: 81 mg
Protein: 21 g
Potassium: 249 mg

Total Fat: 4 g
Cholesterol: 51 mg
Total Fiber: 2 g
Carbohydrates: 11 g

recipe from : https://www.nhlbi.nih.gov/health/educational/healthdisp/pdf/recipes/Recipes-African-American.pdf
& https://extension.purdue.edu/foodlink/recipe.php?recipe=Smothered%20Greens

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Recipe Selection

Smothered Greens & Chicken Gumbo

- culturally relevant - soul food to match the population of Gary
  - food is familiar, allows us to introduce more vegetables into diet
- healthy - full of vegetables, low fat
- fresh vegetables from CSA package, discourages eating processed foods
  - maximizes produce usage for the month, uses 6 crops from the season

http://louisiana.kitchenandculture.com/sites/default/files/styles/large/public/recipes/Louisiana%20Kitchen%20%26amp%3B%20Culture/mustard-greens-bacon.jpg
https://images-gmi-pmc.edge-generalmills.com/f4c9149f-0221-486b-b492-a5725f9b4895.jpg

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LOGIC MODEL AND PARTNERING WITH FRANCISCAN

Goal: Increase Community Health by Implementing CSA Program					
INPUTS	**ACTIVITIES**		**OUTCOMES**		
What we invest	**What we do**	**Who we reach**	**Why this project: short-term results**	**Why this project: intermediate results**	**Why this project: long-term results**
Volunteers Staff Money Crops Fish Materials Equipment Team of 10+ engineering students	Provide fresh produce Provide recipes for how to use fresh produce Provide opportunities to learn about where your food comes from Partner with local food pantries and churches	Low-income population of Gary Those without access to fresh produce	Members of the community will have access to fresh produce Members of the community will have knowledge of how to use fresh produce Increase of intake of fresh fruits and vegetables	Community members will have a better understanding of how their diet affects their health Promote health-conscious eating habits	Improved health of the community Lower rates of diseases such as cardiovascular disease, diabetes, and obesity Improved quality of life for the community

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Spring 2020 Semester Deliverables

Phase 2: Packages

1. Source Containers for Packages
2. Connect with Regional Food Pantries
3. Branding Packages
4. Advertising CSA Program to the Community

Ongoing: Grants

1. Begin Live Impact Grant

Summer 2020 Pilot Program

FARM PLAN PROGRAM

<u>Senior Design Project</u>

Multidisciplinary Engineering

Concentration: Humanitarian Engineering

EPICS / PURDUE

1. The Farm Plan Program incorporates the field’s past crops, availability of fields and infrastructure, and projected climate for the year to recommend plants
2. It involves strategic decisions that manage pests and maintain and increase the quality of the land through crop rotation and companion planting
3. The Farm Plan Program calculates the amount of produce, cost of seeds, and the expected number of Gary families served

Design Considerations: Crop Rotation

Plants by Family

Crucifer
Cabbage
Broccoli
Collard
Kale
Mustard
Radish
Turnip

Legume
Peas
Beans

Nightshade
Tomatoes
Peppers

Beetroot
Beets
Spinach

Allium
Onion

Marrow
Cucumbers
Squash
Watermelon

Miscellaneous
Iceburg
Lettuce
Marigold
Okra
Romaine

Parsley
Carrots

Benefits:

- ➔ Soil Quality
- ➔ Disease Control
  - ➔ Determined by Crop's Family

Desired Crop Rotation

Nightshade ⇨ Onion or Pea + Bean ⇨ Cabbage ⇨ Nightshade ⇨ Carrot ⇨ Marrow or Beetroot ⇨ Pea + Bean ⇨ Nightshade

EPICS / PURDUE

Design Considerations: Companion Planting

Example Companion Pairs

Soil Enhancement	
Selected Plant	*Companion*
Beets	Beans
Broccoli	Beets
Carrot	Beans
Cucumber	Beans
Cabbage	Beets
Collard	Beets
Onion	Beets
Squash	Beans

Weed Suppressant	
Selected Plant	*Companion*
Beans	Squash
Watermelon	Lettuce
Watermelon	Radish

Companion Planting

Purposely Planting in Close Proximity to Enhance Growth

Benefits:

- → Pest Repellent
- → Soil Enhancement
- → Natural Support
- → Weed Suppressant

EPICS / PURDUE

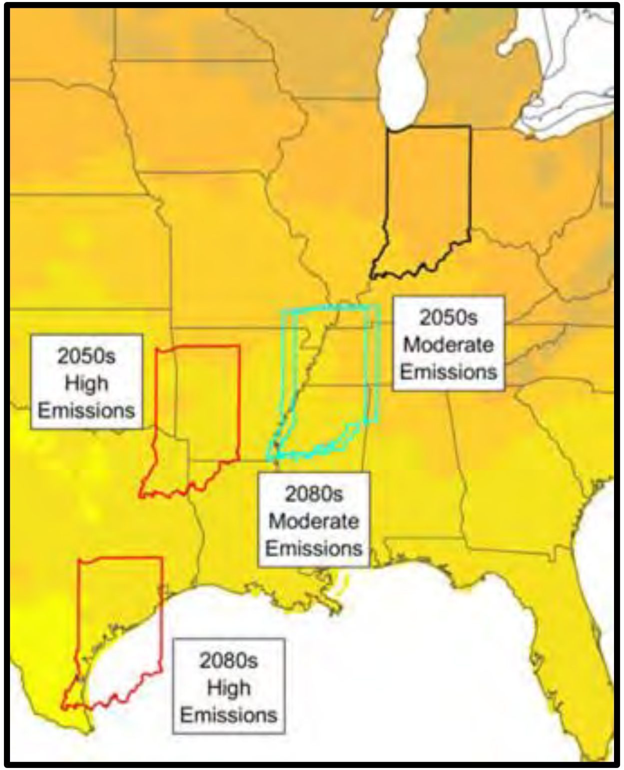
Design Considerations: Climate Change

Projected Summers in Indiana

- → Mississippi + Arkansas

Projected Changes in Indiana

- → Warmer annual, seasonal and growing-season temperatures
- → Increased frequency and magnitude of extreme heat
- → Increased annual, winter and spring precipitation
- → Increased frequency of heavy precipitation events
- → Increased soil saturation early in the growing season



https://ag.purdue.edu/indianaclimate/indiana-climate-report/

EPICS PURDUE

Design Considerations: Field Availability

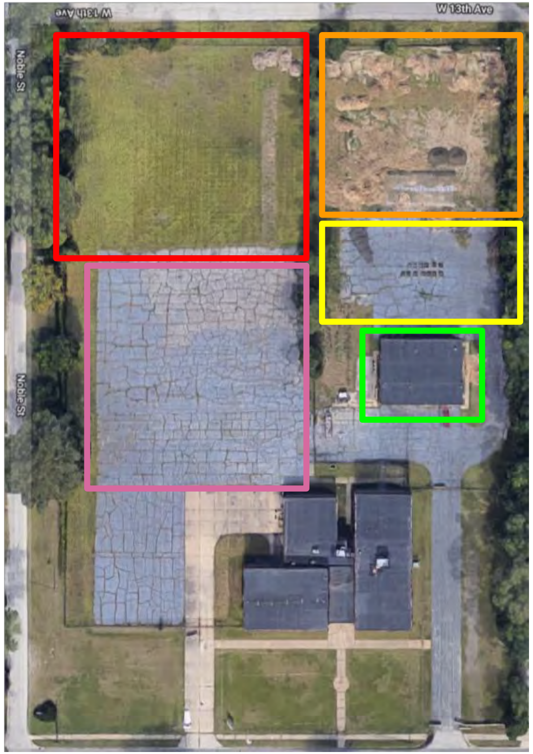
Field B

Hoop House x 6

Field C

Raised Beds

Number Currently Undetermined



Field A

Hoop House x 3

Plot x 3

Field D

Raised Beds

Number Currently Undetermined

Plot x 4

Motorpool

Aquaponics Unit x 40

EPICS / PURDUE

Example Scenario: Hoop House 1, Field A

IF something was planted in **Hoop House 1** last year, what is reccomended to be planted this year is dependent on what was **planted last year**

Crop Rotation			
Plant	**Planted Last Year?**	**Reccomended This Year**	**Selected Plant**
Beets	N	N	
Spinach	N	N	
Broccoli	N	N	
Cabbage	N	N	
Collard	N	N	
Kale	N	N	
Mustard	N	N	
Radishes	N	N	
Turnips	N	N	
Carrots	N	N	
Cucumbers	N	N	
Squash	N	N	
Watermelon	N	N	
Iceberg	N	Y	
Lettuce	N	Y	
Marigolds	N	Y	
Okra	N	Y	
Romaine	N	Y	
Peppers	N	N	
Tomatoes	N	N	
Onions	N	N	
Beans	N	N	
Peas	N	N	

The user can select one of the ***reccomended plants from D6-28*** or ***reccomended pairs from H6-29*** that consider benefits like natural support, weed suppressant, pest repellent, or soil ehancement

Companion Planting			
Companion 1	**Companion 2**	**Reccomended Pair**	**Selected Plant**
Beans	Sunflower	N	
Cucumber	Sunflower	N	
Squash	Corn	N	
Beets	Beans	N	
Broccoli	Beets	N	
Carrot	Beans	N	
Cucumber	Beans	N	
Cabbage	Beets	N	
Collard	Beets	N	
Onion	Beets	N	
Squash	Beans	N	
Broccoli	Rosemary	N	
Cabbage	Rosemary	N	
Kale	Rosemary	N	
Turnips	Rosemary	N	
Iceberg	Basil	Y	
Lettuce	Basil	Y	
Romaine	Basil	Y	
Peppers	Basil	N	
Radishes	Basil	N	
Squash	Borage	N	
Tomatoes	Basil	N	
Watermelon	Lettuce	N	
Watermelon	Radish	N	

Selected Plant	Companion

EPICS / PURDUE

Example Scenario: Hoop House 1, Field A

IF something was planted in **Hoop House 1** last year, what is reccomended to be planted this year is dependent on what was **planted last year**

Crop Rotation			
Plant	**Planted Last Year?**	**Reccomended This Year**	**Selected Plant**
Beets	N	Y	
Spinach	N	Y	
Broccoli	N	N	
Cabbage	N	N	
Collard	N	N	
Kale	N	N	
Mustard	N	N	
Radishes	N	N	
Turnips	N	N	
Carrots	Y	N	
Cucumbers	N	Y	
Squash	N	Y	
Watermelon	N	Y	
Iceberg	N	Y	
Lettuce	N	Y	
Marigolds	N	Y	
Okra	N	Y	
Romaine	N	Y	
Peppers	N	N	
Tomatoes	N	N	
Onions	N	Y	
Beans	N	Y	
Peas	N	Y	

The user can select one of the ***reccomended plants from D6-28*** or ***reccomended pairs from H6-29*** that consider benefits like natural support, weed suppressant, pest repellent, or soil ehancement

Companion Planting			
Companion 1	**Companion 2**	**Reccomended Pair**	**Selected Plant**
Beans	Sunflower	Y	
Cucumber	Sunflower	Y	
Squash	Corn	Y	
Beets	Beans	Y	
Broccoli	Beets	N	
Carrot	Beans	N	
Cucumber	Beans	Y	
Cabbage	Beets	N	
Collard	Beets	N	
Onion	Beets	Y	
Squash	Beans	Y	
Broccoli	Rosemary	N	
Cabbage	Rosemary	N	
Kale	Rosemary	N	
Turnips	Rosemary	N	
Iceberg	Basil	Y	
Lettuce	Basil	Y	
Romaine	Basil	Y	
Peppers	Basil	N	
Radishes	Basil	N	
Squash	Borage	Y	
Tomatoes	Basil	N	
Watermelon	Lettuce	Y	
Watermelon	Radish	Y	

Selected Plant	Companion

EPICS / PURDUE

Example Scenario: Hoop House 1, Field A

IF something was planted in **Hoop House 1** last year, what is reccomended to be planted this year is dependent on what was **planted last year**

Crop Rotation			
Plant	**Planted Last Year?**	**Reccomended This Year**	**Selected Plant**
Beets	N	Y	
Spinach	N	Y	
Broccoli	N	N	
Cabbage	N	N	
Collard	N	N	
Kale	N	N	
Mustard	N	N	
Radishes	N	N	
Turnips	N	N	
Carrots	Y	N	
Cucumbers	N	Y	
Squash	N	Y	
Watermelon	N	Y	
Iceberg	N	Y	
Lettuce	N	Y	
Marigolds	N	Y	
Okra	N	Y	
Romaine	N	Y	
Peppers	N	N	
Tomatoes	N	N	
Onions	N	Y	
Beans	N	Y	
Peas	N	Y	

The user can select one of the ***reccomended plants from D6-28*** or ***reccomended pairs from H6-29*** that consider benefits like natural support, weed suppressant, pest repellent, or soil ehancement

Companion Planting			
Companion 1	**Companion 2**	**Reccomended Pair**	**Selected Plant**
Beans	Sunflower	Y	
Cucumber	Sunflower	Y	
Squash	Corn	Y	X
Beets	Beans	Y	
Broccoli	Beets	N	
Carrot	Beans	N	
Cucumber	Beans	Y	
Cabbage	Beets	N	
Collard	Beets	N	
Onion	Beets	Y	
Squash	Beans	Y	
Broccoli	Rosemary	N	
Cabbage	Rosemary	N	
Kale	Rosemary	N	
Turnips	Rosemary	N	
Iceberg	Basil	Y	
Lettuce	Basil	Y	
Romaine	Basil	Y	
Peppers	Basil	N	
Radishes	Basil	N	
Squash	Borage	Y	
Tomatoes	Basil	N	
Watermelon	Lettuce	Y	
Watermelon	Radish	Y	

Selected Plant	Companion
Squash	Corn

EPICS / PURDUE

Example Scenario: Hoop House 1, Field A

ITERATION 1:	Field = A, Infrastructure = Hoop House		
Plant	**Yield of Plant (pound/acre)**	**Yield of Plant (pound/infrastructure)**	**Yield of Infrastructure (pound/infrastructure)**
Beets	33,440	1658.2	
Beans	9,620	477.0	
Broccoli	15,170	752.2	
Cabbage	71,980	3569.3	
Carrots	82,760	4103.8	
Collard	23,800	1180.2	
Cucumbers	27,860	1381.5	
Iceberg	67,440	3344.1	
Kale	35,800	1775.2	
Lettuce	67,440	3344.1	
Marigolds	1,000	49.6	
Mustard	25,600	1269.4	
Okra	12,000	595.0	
Onions	111,220	5515.0	
Peas	5,740	284.6	
Peppers	64,960	3221.2	
Radishes	18,400	912.4	
Romaine	60,600	3005.0	
Spinach	27,000	[illegible]	
Squash	33,000	1636.4	1096
Tomatoes	172,760	8566.6	
Turnips	21,400	1061.2	
Watermelon	70,100	3476.0	
Basil	1,000	49.6	
Borage	1,000	49.6	
Corn	30,980	1536.2	507
Rosemary	1,000	49.6	
Sunflower	1,000	49.6	

EPICS PURDUE

Finalization of Project

1. Incorporate
   - Cost of Seeds
   - Recommendations on Field Use Based on Climate Predictions

1. Scale Up to Each Infrastructure and Field

1. Summary Page with Outputs + Cleaner Input Page

EPICS PURDUE

Prototype

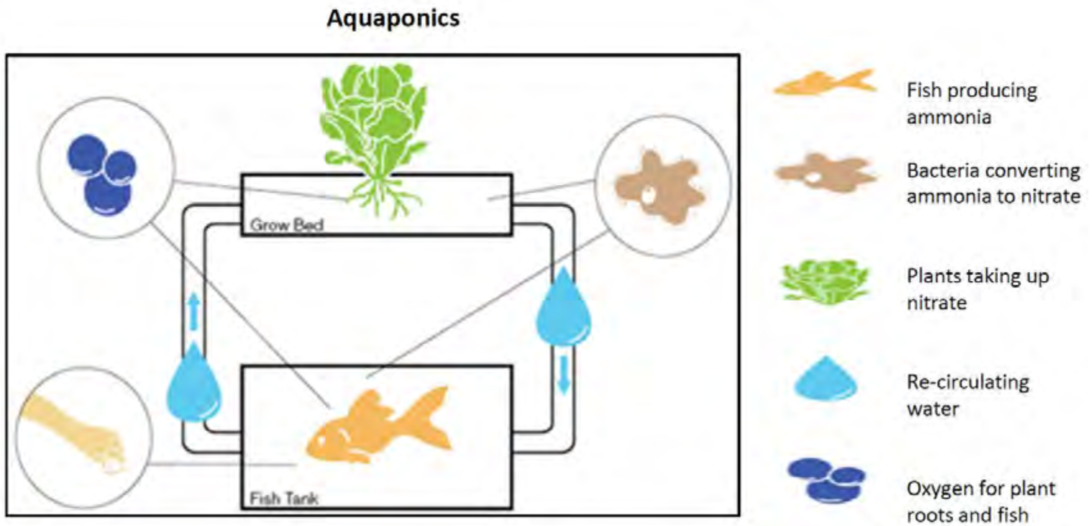
Project Details

EPICS / PURDUE

Prototype Project

Aquaponics System

- Water based growing
- Accessible oxygen
- Symbiotic relationship between fish and plants
- Can grow year round



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Long Term Goals and Deliverable

Gary is located in Plant Hardiness Zone 5.

- Last Frost: Early May
- First Frost: Early October

Provide a reproducible framework for further development of aquaponics systems in Midwestern food deserts.

- Scalable to schools, churches, and community centers

Gary has a shortened growing season

http://hoosiergardener.com/?p=7270

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Vision

3 Phase Build and Testing

- Phase I - 1st row on each side of the fish pool
- Phase II - 1st and 2nd row on each side of the fish pool
- Phase III - all shelving units

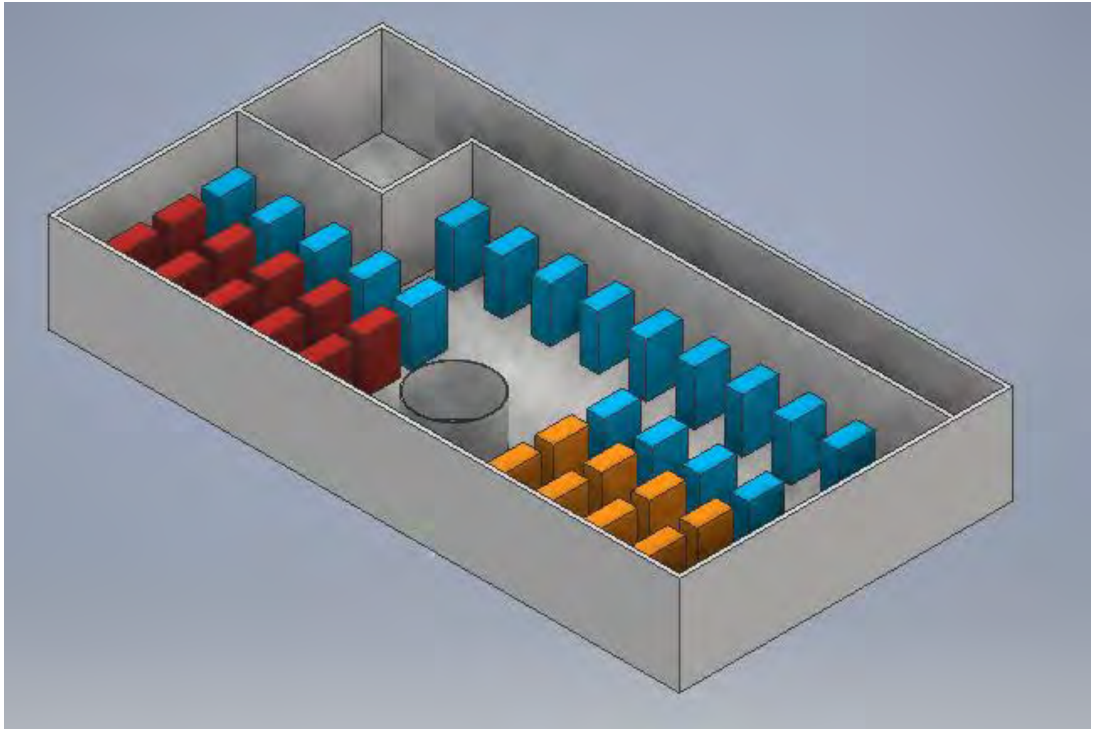

Figure: The envisioned motor pool layout

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Design Requirements

Customer Need	Customer Requirement	Current Performance	Target Value
Size of System	Needs to fit within Motor Pool building footprint	1906 sq. ft	1906 sq. ft
Amount of Food (lettuce)	Must be able to grow for 600 families	2040 lb/year	3600 lb/year
Production Density	Must grow required amount of lettuce in footprint	1.07 lb/(sq. ft * yr)	1.89 lb/(sq. ft * yr)
Cost of System	Needs to be economical	3.80 years to break even	2 years to break even

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Semester Goals and Deliverables

Goals

- To gain insight on how the product will work
- Gather data on how prototype functions
- Measure plant conditions
- Treat water for plant health

Deliverables

- Provide a working prototype
- Consistent flow rate from water spouts
- Successful transplant of lettuce heads

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Semester Timeline

August → **September** → **October** → **November** → **December**

August
- research and finalize purchases
- update CAD design
- develop procedure

September
- install pump, pipes, tank, and secondary tank
- begin germination
-begin sensor design

October
- test water circulation in plant basins
- consider filter design
- plant transplant

November
- test sensors
- gather data for design decisions

December
- take final measurements from prototype
- document reproducible design

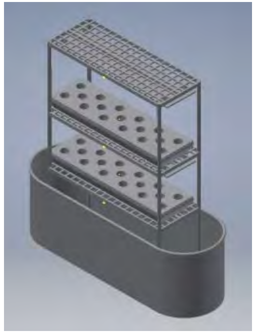
CAD Updates

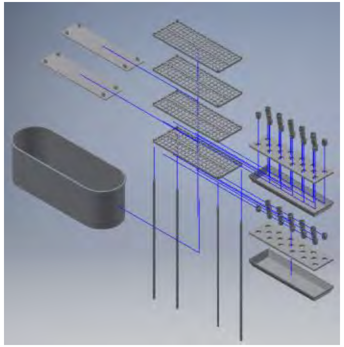
Model Design

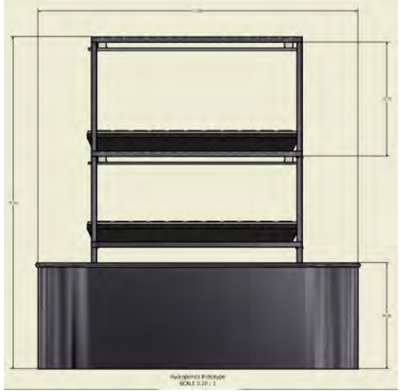
- Previous design needed updating
- New models have been updated to prototype
- New design gives estimates on final product

Previous Prototype Designs

Updated Prototype Designs

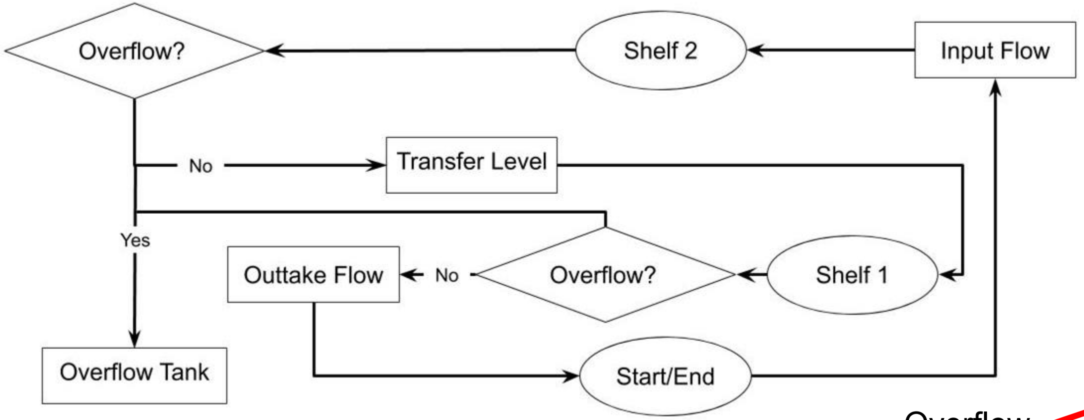






Shelving Design

Flowchart for Flow Between Shelves



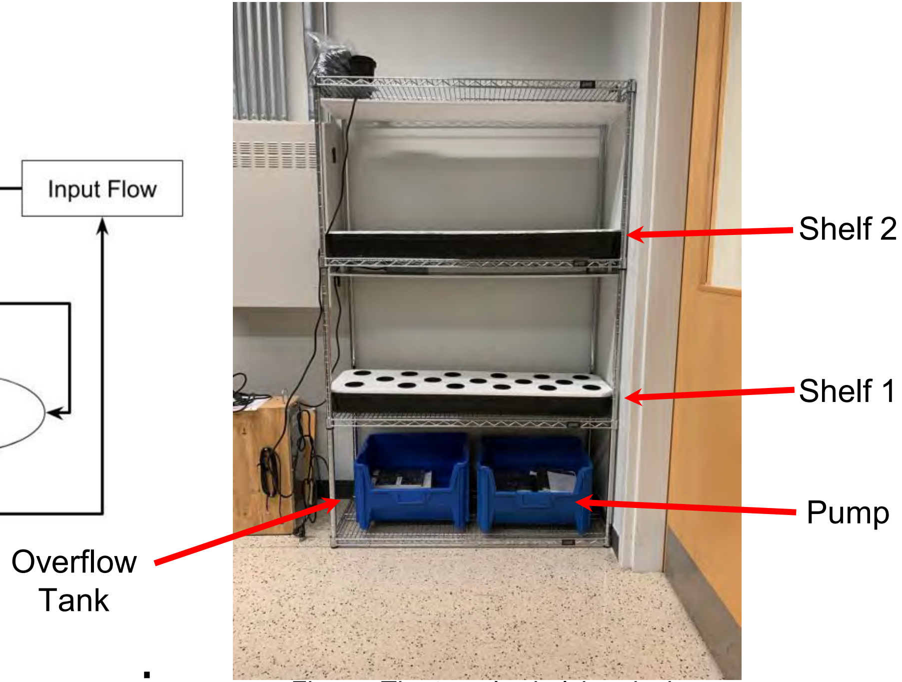


Figure: The team's shelving design

- Shelves allow for high density growing

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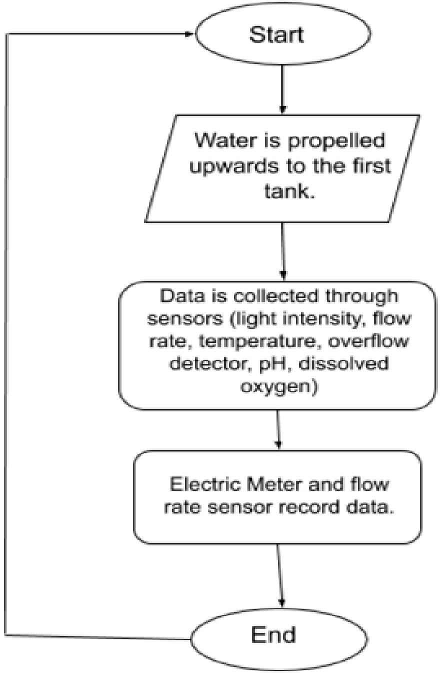
Pipe Design

- PEX pipes to circulate water between trays

An Example Pipe Set-up from Site Visit



Flowchart for recording data in pipes

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Pipe Diameter Selection

PEX Piping

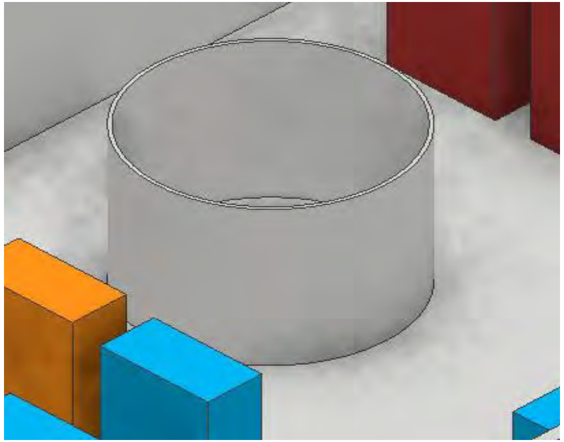
https://www.alibaba.com/product-detail/Advertising-Pex-Pipe-With-Warranty_60711286329.html

$$\frac{p_1}{\gamma_w} + z_1 + \frac{V_1^2}{2g} + h_{pump} = \frac{p_2}{\gamma_w} + z_2 + \frac{V_2^2}{2g} + h_L$$

- Use Bernoulli’s equation
- Based on elevation head differentials
- Utilized PEX Pipe roughness height to select friction factor
- 1 Inch Piping at Minimum

Tank Design Selection

- 1:2 fish to plant ratio
  - 2,040 plant sites
  - 1,020 fish total
- Fish need 1-2 gallons for every pound
  - 612 gallons
- Calculated water for trays
  - ~10 gal/tray x 120 trays = 1,200 gallons
- 2000 gallon tank at minimum (5 ft tall, 8 ft diameter)
  - Poly Processing



The envisioned fish tank modeled in CAD

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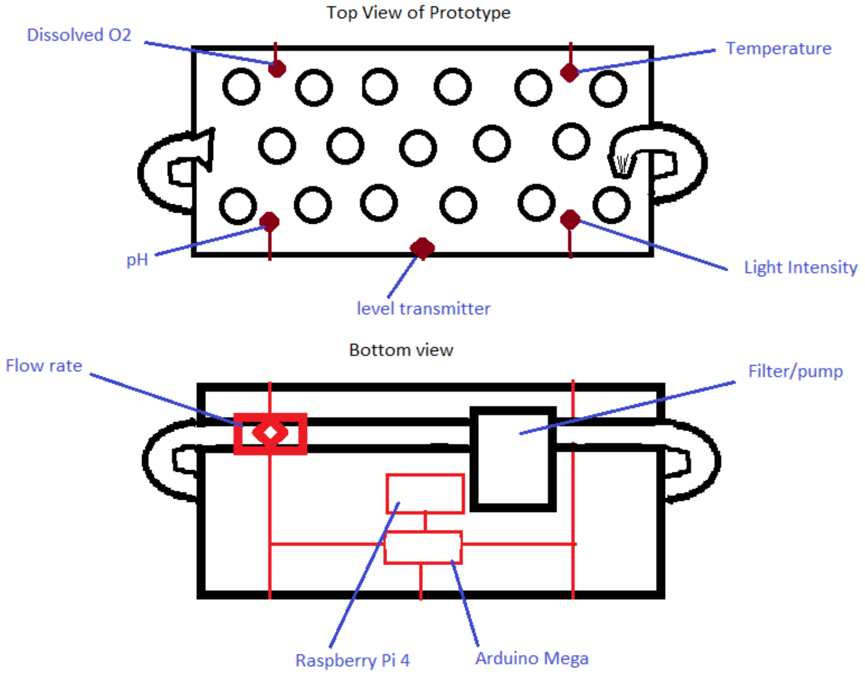
Sensor Design

Sensors Selected

- Light intensity
- Flow Rate
- Temperature
- Overflow Detector
- pH
- Dissolved Oxygen



Figures: Sensor layout plan

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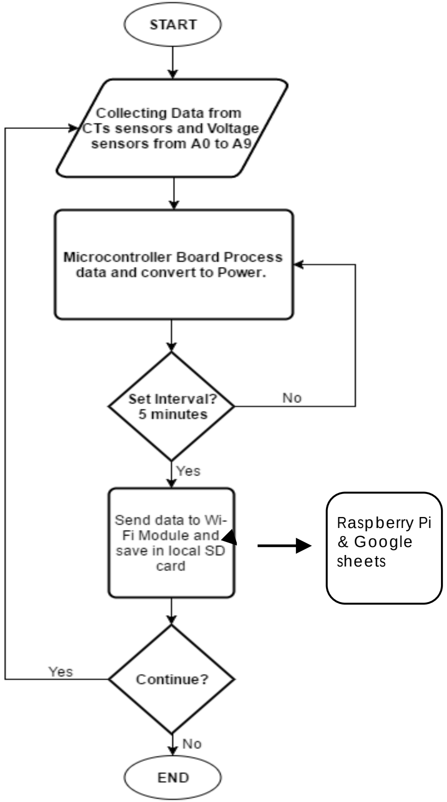
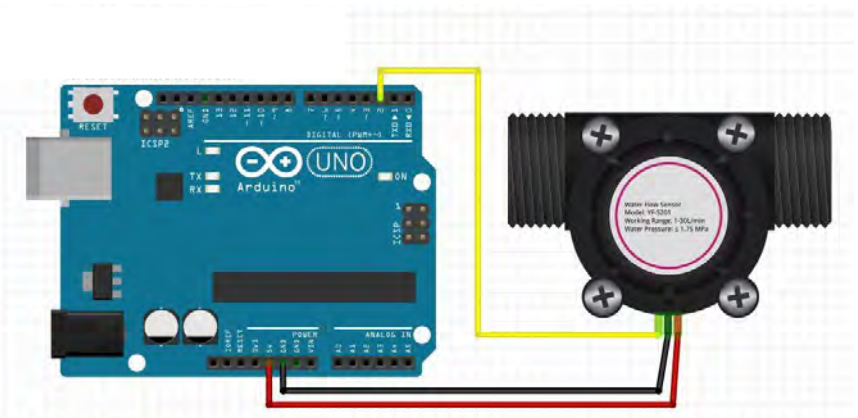
Sensor Flowchart

- Looping design to gather sensor data
- Outputs to google spreadsheet





Sample sensor connection to Arduino https://cdn.instructables.com/F2S/7PK4/ION6O0G9/F2S7PK4ION6O0G9.LARGE.jpg?auto=webp&fit=bounds

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Sensor Sample Output

Sensor Type	Current data	Min in past 48 hours	Max in past 48 hours
Flow Rate (lpm)	11.36	11.33	11.36
Water Temperature (celcius)	21.11	20.13	21.37
pH	8.32	7.99	8.43
Dissolved O2 (ppm)	10	8	11

Sample Sensor Output to Google Sheets

Produce Decision Matrix

Criteria	Weight	Pea Microgreens	Tomatoes	Lettuce	Peppers
Cost of Seeds	1	2	2	5	2
Project Partner Input	3	2	3	5	3
Time to Germinate	2	5	3	4	2
Ease of Transplanting	4	3	3	2	1
Time to Harvest	4	5	3	3	2
Totals		50	41	48	27

5 = Desirable
1 = Non-desirable

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Regermination

- Fixing previous mistakes
  - Germination method
  - Light consistency
  - Water levels unknown before
- Regermination:
  - Controlling light
  - Time of transplant
  - Water testing

Figure: First germination of lettuce seeds

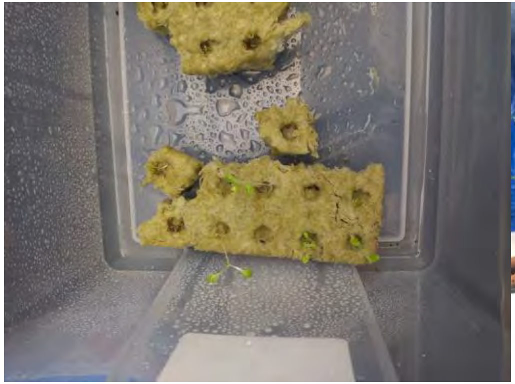

Figure: Second batch of lettuce seeds

Figure: Pea Microgreens

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Final Produce List

- Cabbage (Brassica oleracea)
- Collard Greens (Brassica oleracea)
- Lettuce (Lactuca sativa)
- Mustard Greens (Brassica juncea)
- Spinach (Spinacia oleracea)
- Basil (Ocimum basilicum)
- Chives (Allium schoenoprasum)
- Dill Weed (Anethum graveolens)
- Parsley (Petroselinum crispum)

Figure: Pea Microgreens were transplanted into the hydroponics prototype three weeks after we began germinating them

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Collected Data

Nitrogen Concentrations

- Ammonia levels
  - Healthy: 0.25 ppm
  - Current: 0.25 ppm
- Plants are not converting ammonia to nitrate and then nitrite
- Dangerous for fish health
  - Illness → death

■ Ammonia → Water dilution
■ Nitrate → Vinegar
■ Nitrite

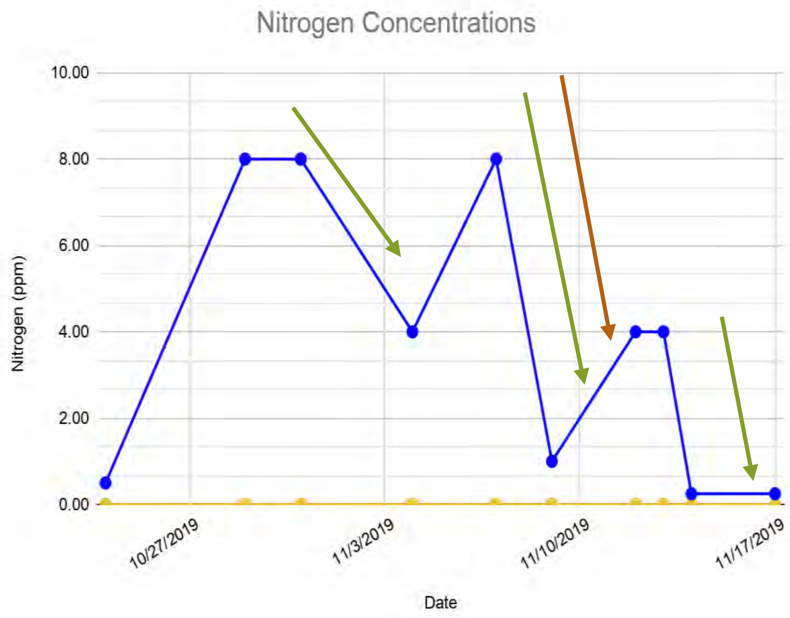

Figure: Nitrogen concentrations of tested water

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Collected Data

pH Levels

- pH levels are relatively too high for the plants
- Vinegar will lower the pH
  - Added 11/7
- Baking soda will raise the pH
- Our optimal pH level is between 6.5 and 7.0

→ Added vinegar

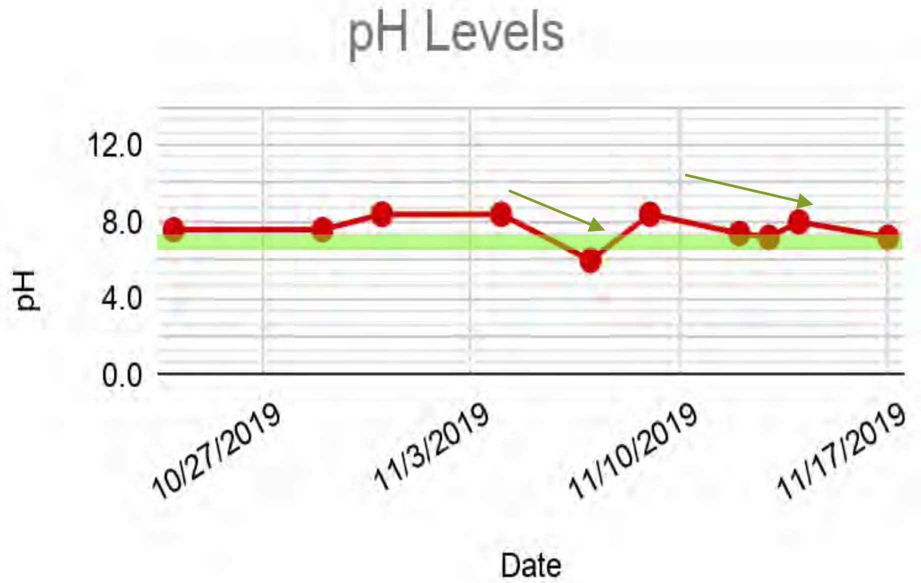

Figure: PH levels in system over the last three weeks

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Next Steps

Incorporating Fish

- Bluegill and Lake Perch
  - 17 of either fish species in the prototype
    - 2 fish will be plenty
  - Must maintain ammonia levels
  - Monitoring fish health and growth rates
- Feeding
  - Twice per day
    - Morning
    - Night
  - Lowers fish cannibalism

https://en.wikipedia.org/wiki/Yellow_perch
https://en.wikipedia.org/wiki/Bluegill

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Final Aquaponics Design

Production Rates

- Plants
    - 2,040 plants total
    - 9,800 heads of lettuce per year
- Fish
    - 1,020 fish total
    - Bluegill - 1,020 lbs/year
    - Lake Perch - 510 lbs/year

Cost of Operation = $1,340/year for lights and pump

Example growth from Site Visit

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Prototype vs. Commercial Systems Comparison

- Prototype costs more than pre-made commercial systems per plant
- However, commercial designs are not space optimal and are not modular
- **In urban spaces where space is limited, our superior production density justifies our prototype design**

Example of commercial growing system (horizontal)

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Next Steps to Achieve Design Requirements

- Optimize shelving design (4 shelves instead of 3 per unit)
- Analyze potential for material reuse
- Consider bulk or local purchasing for materials
- Continue to refine sensor design
- Material reuse for large scale filter

Example of filter media used in a large scale system

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Finance

Project Details

Semester Timeline

August → September → October → November → December

August
- Comparison of market system vs prototype system
- Service learning grant
- Purchase requests
- Create budget phases

September
- Purchase Requests
- Grants
- Comparison of market system vs prototype system
- Create a budget sheet of prototype materials
- Contact engineers and contractors for renovation costs

October
- Scaling prototype budget form for phase one
- Create grant template
- Contact engineers and contractors for renovation costs
- Purchase requests

November
- Contact engineers and contractors for renovation costs
- Create grant template
- Find and apply for grants
- Scale prototype for phase two and three
- Purchase requests

December
- Find and apply for grants
- Purchase requests
- Contact contractors to start renovation on motorpool
- Complete estimation of total project

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Phase Costs

	Phase 1	Phase 2	Phase 3	Totals With 3 Years of Operation	
Installation	$11,779	$9,597	$19,194	$40,569	
Renovations/ General Maintenance	$18,803	$960	$1,919	$21,682	
Prototype	$1,977	$0	$0	$1,977	
Operations (1 Year)	$4,549	$4,949	$5,751	$15,249	
Total	$37,108	$15,506	$26,864	$79,478	** Total Budget within 15% of Estimated Budget

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Modelling Heating and Cooling Costs

Sensitivity Analysis

High	$727.51
Medium	$1,171.57
Low	$2,704.00

$$Heat\ Loss = \frac{1}{R} * A * t$$

- R = resistance to heat loss (insulation)
- A = surface area of the building
- T = time

Takeaway - Must optimize insulation to lower costs

Calculations taken from Mihelcic (2014) Env. Engineering Textbook

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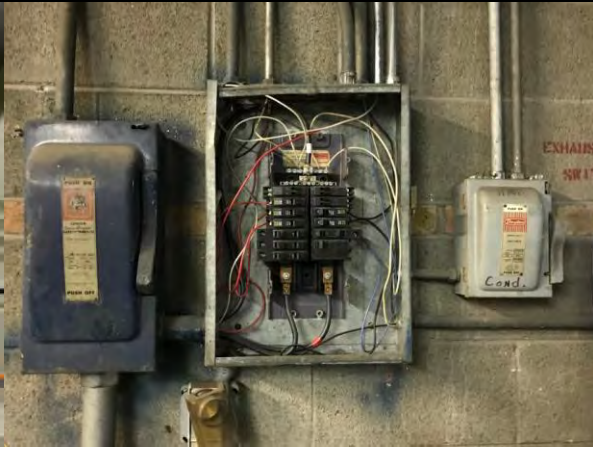
Building Retrofitting



Building Needs

- HVAC
- Insulation
- Electric Capacity
- Structural Integrity

Engineers Contacted

- Enspect Engineering Consultants
- Falk Pli
- CDM Smith
- Inquired about company's ability to Perform As-Built Strength Assessments, Perform HVAC Analysis, Rewire Electrical, and Update Insulation.

FALK PLI

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Current Budget

Material	Quantity	Unit Price	Shipping	Total Price
Ph sensor	1	164.00	0.00	$164.00
Dissolved Oxygen Sensor	1	290.79	0.00	$290.79
Electricity Usage Monito	2	24.19	0.00	$48.38
Thermometer	4	9.99	0.00	$39.96
Flow Meter	2	12.99	0.00	$25.98
Arduino	1	14.99	0.00	$14.99
Arduino Charger	1	8.99	0.00	$8.99
Lettuce Seeds	1	1.95	0.00	$1.95
1' x 4' Flood Table	2	16.01	0.00	$32.02
1' x 4' LED lights	2	165.75	217.18	$548.68
Polystyrene Foam	1	15.02	0.00	$15.02
Sensorpush wireless ther	2	$49.99	0	$99.98
API freshwater Test Kit	1	$22.54	0	$22.54
8x10 Tarp	1	$7.99	0	$7.99
Hydronic Heating Pad	2	$11.99	0	$23.98
API Phosphate Test Kit	1	$12.50	0	$12.50
			Total Price	$1,977

Cost and Profit Calculations

Net Annual Revenue Per Phase

(annual plant revenue + annual fish revenue - estimated annual cost)

Net Annual Revenue Phase 1				
	Iceberg	Collard Greens	Mustard Greens	Romaine
Blue Gill	$4,056	$1,822	$1,594	$6,174
Lake Perch	$3,943	$1,709	$1,481	$6,060

Net Annual Revenue Phase 2				
	Iceberg	Collard Greens	Mustard Greens	Romaine
Blue Gill	$8,415	$3,947	$3,491	$12,649.
Lake Perch	$8,189	$3,721	$3,265	$12,423

Net Annual Revenue Phase 3				
	Iceberg	Collard Greens	Mustard Greens	Romaine
Blue Gill	$17,132	$8,196	$7,284	$25,601
Lake Perch	$16,680.	$7,744	$6,832	$25,149

Revenue calculations assume that each type of lettuce is grown at full capacity and sold at local store prices and that fish are sold once a year at local prices

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Profit, ROI, and Payback Period

Needed Investment

Estimated startup costs					
	Phase 1	**Phase 2**	**Phase 3**	**Renovations**	**Total**
Cost	$18,305	$14,546	$24,945	$21,682	$79,478

Estimated Payback Period of each lettuce/fish combination

Assumes the profit is derived from the local sale prices of each food item

Payback Period (years)				
	Iceberg	**Collard Greens**	**Mustard Greens**	**Romaine**
Blue Gill	5.1	9.2	10.3	3.8
Lake Perch	5.2	9.7	10.8	3.9

10 year Estimation of Profit and ROI

Assumes the profit is given by the combination with the shortest payback period (Romaine + Bluegill)

Year	Net Profit	Profit/year	ROI
1	-$20,654	-$20,654	-0.7699
2	-$21,305	-$651	-0.5309
3	-$20,758	$546	-0.3185
4	$4,842	$25,601	0.0743
5	$30,444	$25,601	0.4671
6	$56,046	$25,601	0.8598
7	$81,648	$25,601	1.2526
8	$107,249	$25,601	1.6453
9	$132,851	$25,601	2.0381
10	$158,453	$25,601	2.4308

Profit and ROI include the installation year and cost at the maximum estimated profit and phase cost

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Comparison (Phase 1)

EPICS Solution Startup Costs

Estimated startup costs					
	Phase 1	**Phase 2**	**Phase 3**	**Renovations**	**Total**
Cost	$18,305	$14,546	$24,945	$21,682	$79,478

Estimated OTS (Off The Shelf) Cost & Sqft Comp

Current Aquaponics OTS Solutions					
Product Name	Rack Sqft	Grow Sqft	Sqft Comp	Cost	Rank
EPICS	480.00	120.00	4	$18,305	3
FarmTek	672.00	256.00	2.6	$12,185	1
Aquaponics	880.00	288.00	3	$19,995	2

Estimated OTS (Off The Shelf) Cost & Yield Comp

Current Aquaponics OTS Solutions					
Product Name	Lettuce (heads) Yield	Fish (lb) Yield	Yield Comp (Ths)	Cost	Rank
EPICS	3,060	255	780	$18,305	3
FarmTek	2,268	520	1,179	$12,185	1
Aquaponics	1,296	970	1,257	$19,995	2

All compared systems are equal to each other in regards to included materials & items.

Grants

Completed

- Service Learning Grant: received $1200 for available funding over the next year

In Progress

- Tomberg Family Philanthropies Grant: began a Letter of Inquiry September 2019 and it is set to be submitted September 2020 with the full grant proposal due in December 2020

Grant Template

- Cover Letter
- Organization Background and Description
- Project Timeline and Budget
- Executive Summary

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Semester Goal

- Prototype Cost and Maintenance vs. A Market Design and Maintenance
- Sent purchase requests for materials to ensure the Prototype & CSA Team has all the necessary supplies.
- Service Learning Grant ($1,200)
- Made our first contact with Engineers and Contractors
- Estimated cost of retrofitting d
- Created a Grant Template -CSA team
- Created complete project budget per phase

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Future Plans

- Partnership with Franciscan Health Hospitals
- Finding and applying to future grants
- Researching methods of selling extra produce
- Research ways we can lower costs of the scalable system
  - Larger shelves
  - Smaller tanks
  - Sensors
  - Optimizing components of the system
- Begin work on motorpool

QUESTIONS |COMMENTS| CONCERNS

THANK YOU