Algal Power
Experimental Research and Design

Group 20

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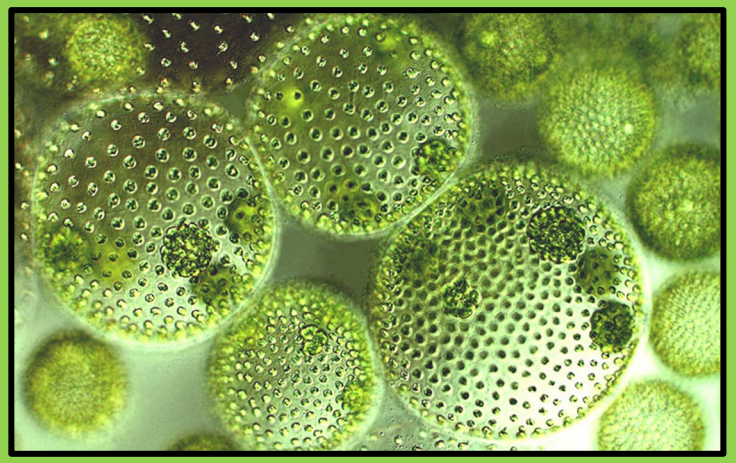
Overview

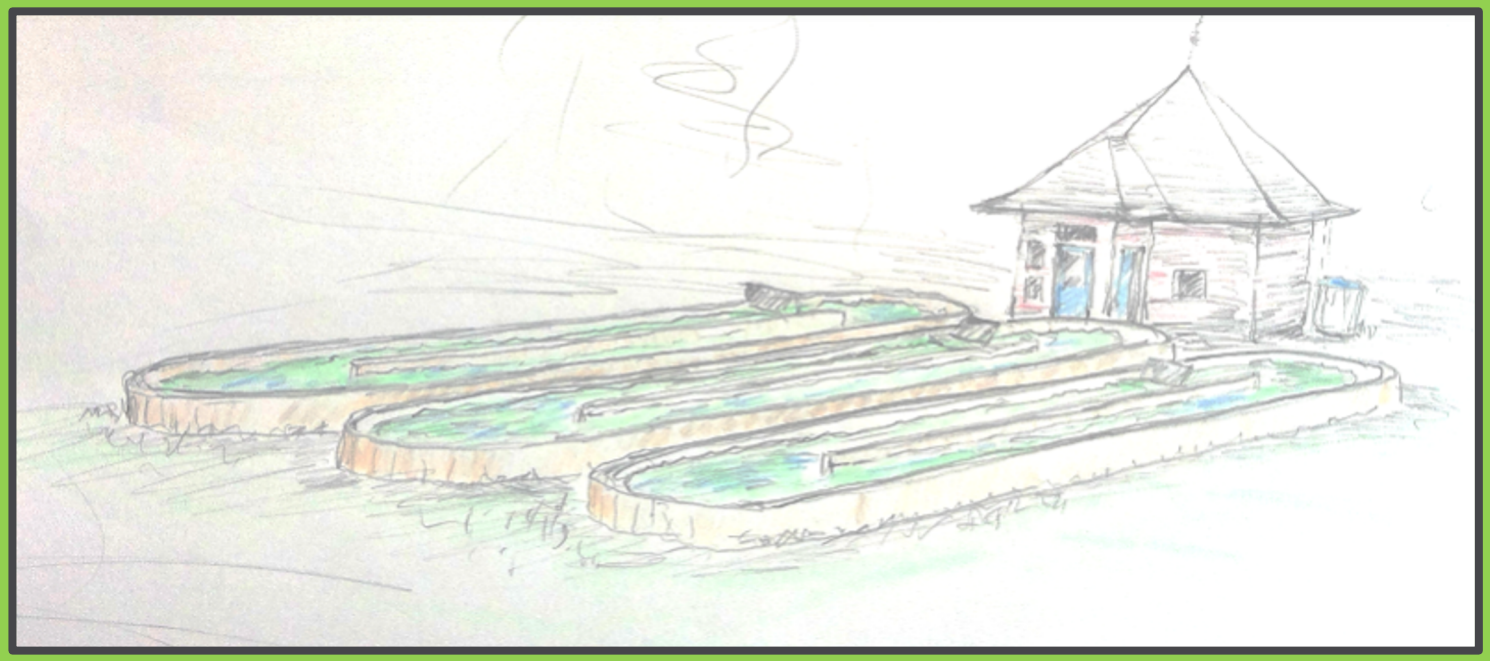
- Project Statement
- Project Background
- Deliverables
- Challenges
- Our Design
- Alternative Designs
- Project Specifics
- Summary



AlgaeVision Colony

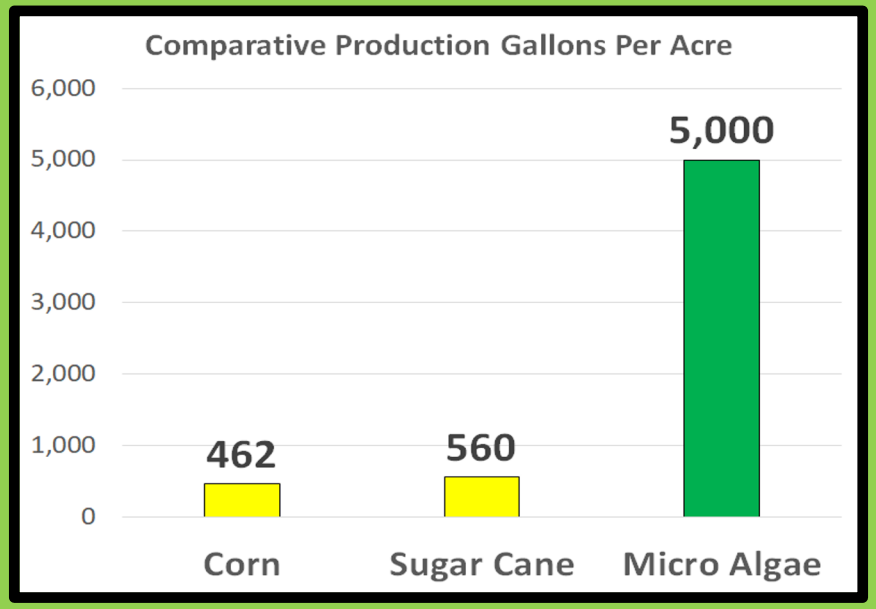
Project Statement

"Create a cost-effective on-site algae to energy system to heat a two person home"



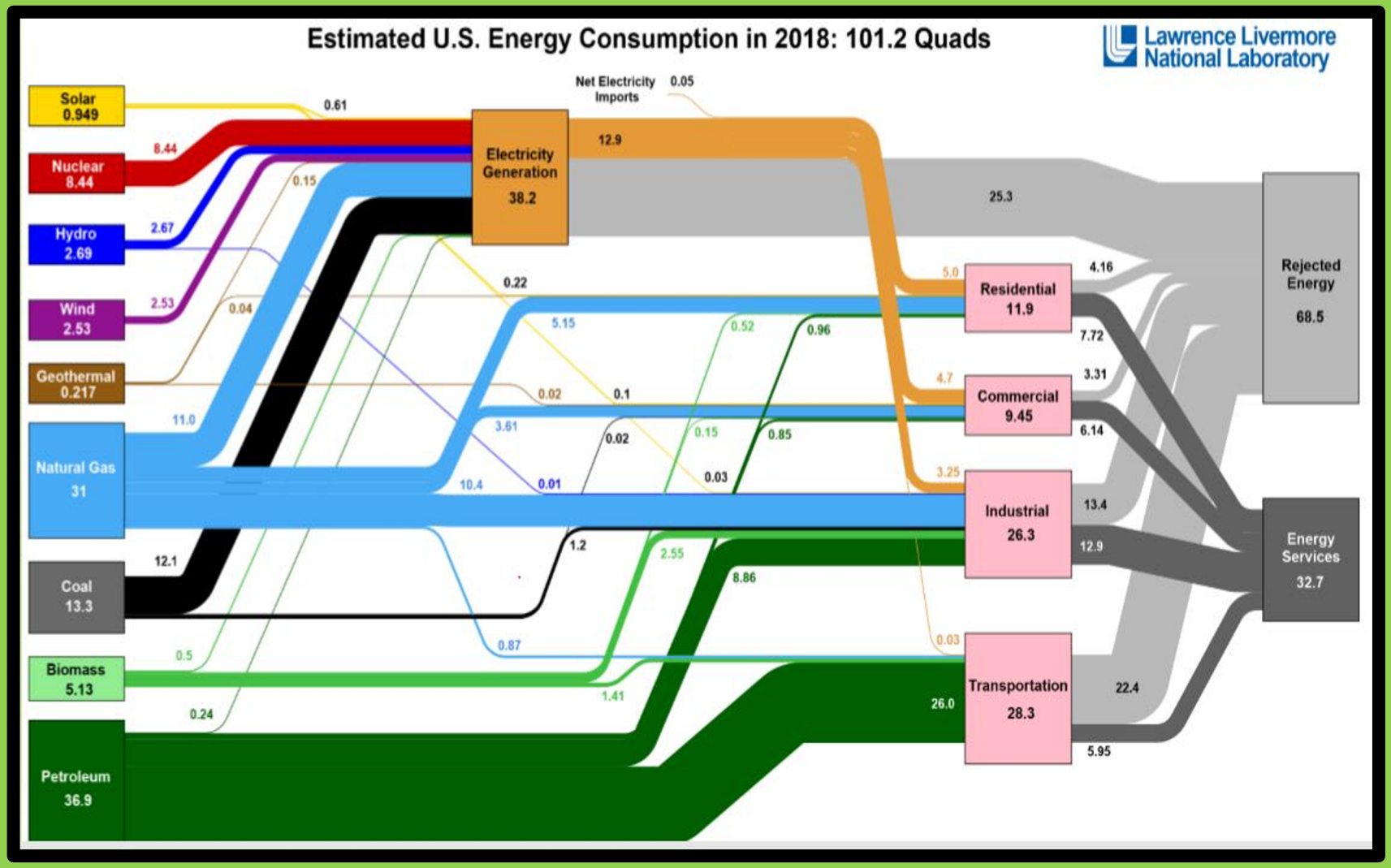
Project Background

- Algae contains high percentages of oils (20-90% based on species)
- Considered for energy for over 100 years
- Large energy companies are now considering algae for energy production
- Fast growth rate, low land use, and high yield per acre



National Renewable Energy Lab (NREL)

Project Background

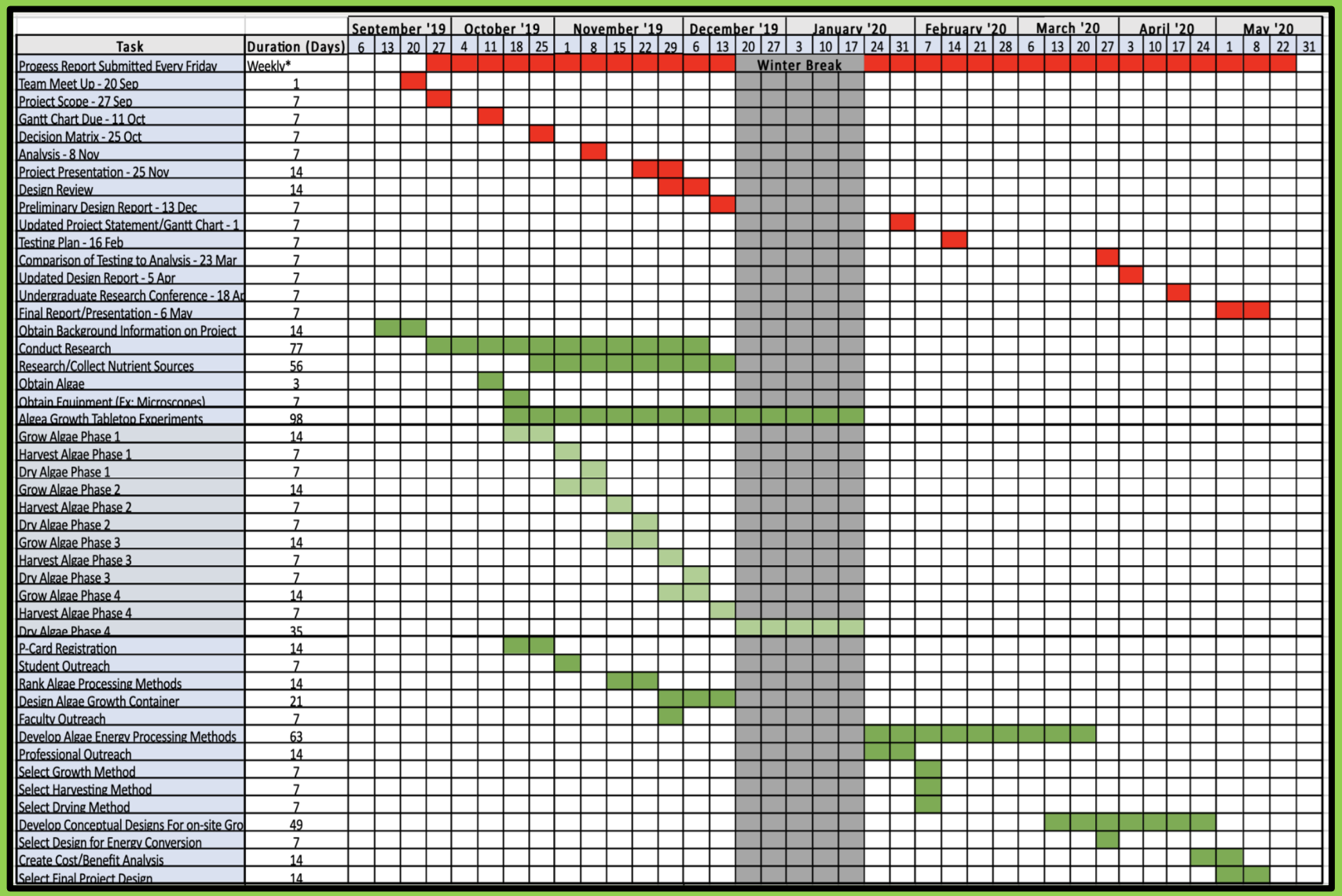


Lawrence Livermore National Laboratory

Deliverables

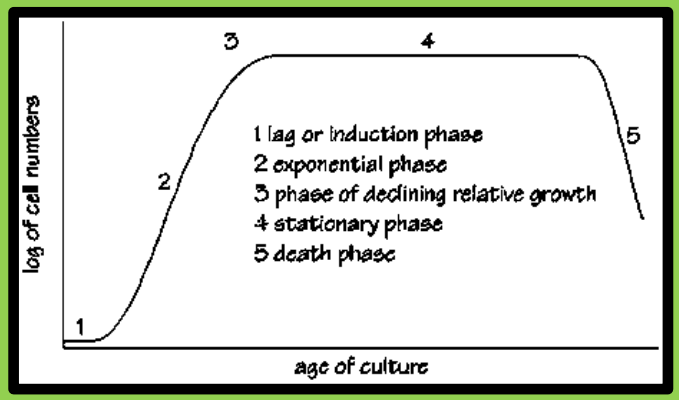
- **Design Reports**
- **Project Presentations**
- **URC Poster**
- **Project Scope**
  - Weekly Meetings/Progress Reports/Work Logs
  - Algae Growth/Harvesting/Energy Conversion Research
  - Conduct Professional/Academic Outreach
  - Request Funding/Resources for Experimental Research
  - Obtain Algae/Nutrient and Conduct Tabletop Experiments
  - Rank Algae Based on Cost/Efficiency/Availability/ Simplicity
  - Design and Build an Algae Growth Raceway
  - Design/Develop Energy Conversion Methods

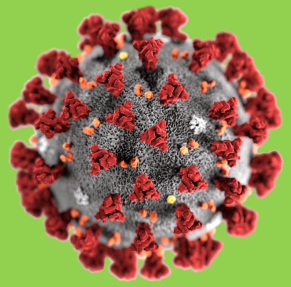
Project Schedule



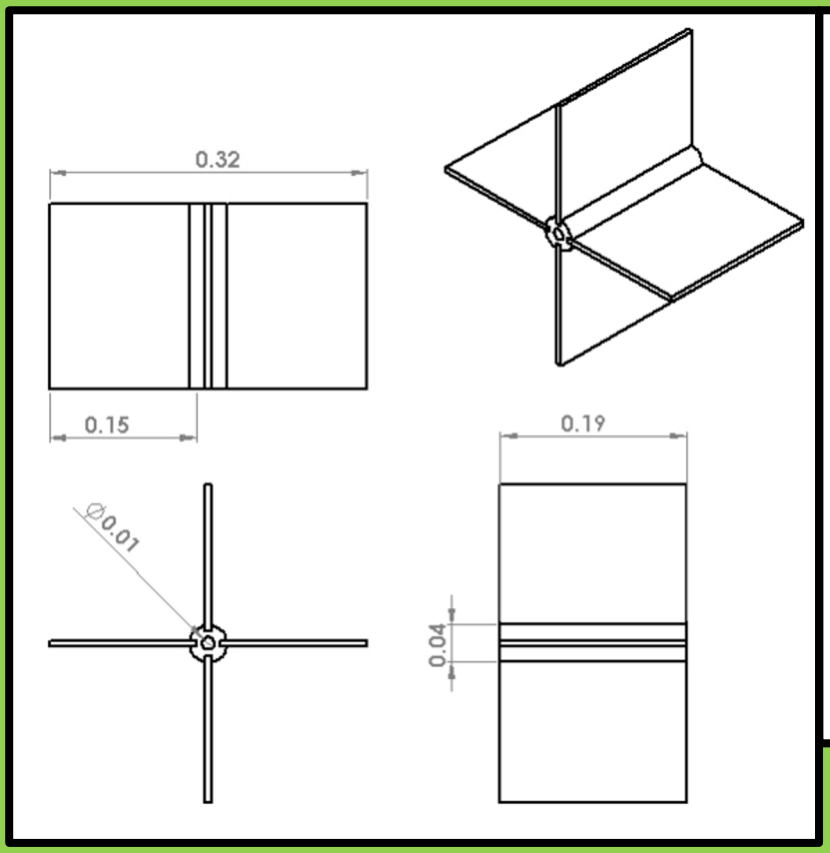
Challenges

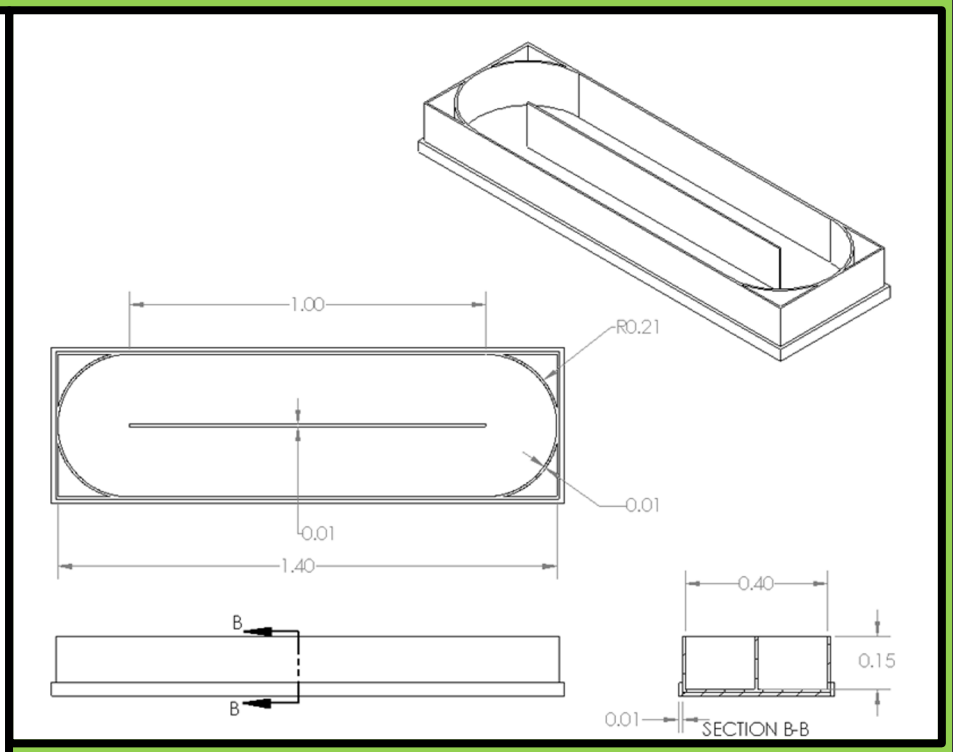
- **Prepare Experiments**
  - Obtaining materials was a slow process
- **Maintaining Algae over break**
  - Keep samples alive/healthy
- **COVID-19**
  - Experiments could not be conducted
  - Meetings held online
- **Results**
  - Lack of experiments/lack of data to compare





Raceway Design Concept

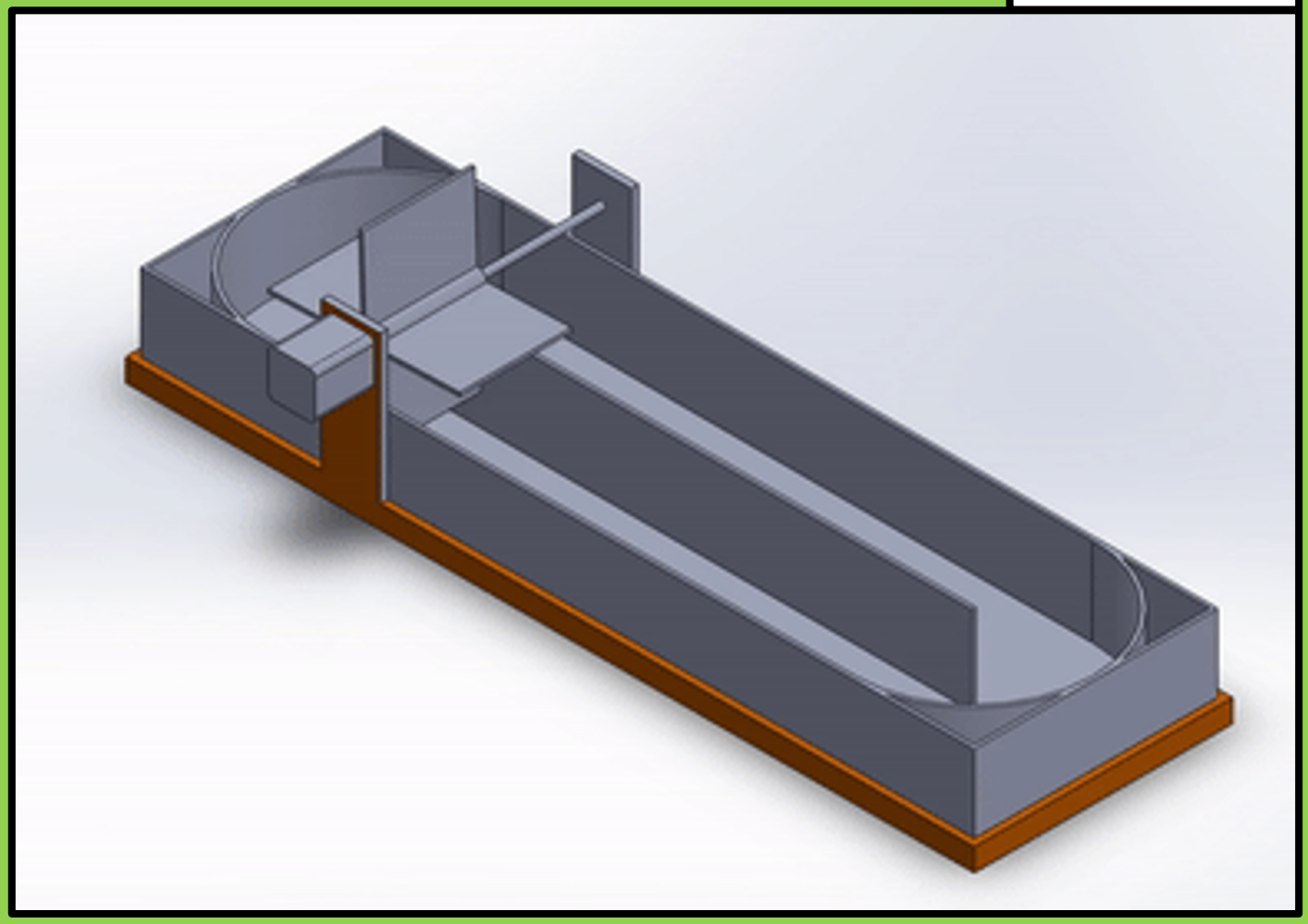




- Open system
- Raceway with attached paddlewheel
- Made of acrylic
- Mixes and suspends algae to help promote growth

Finalized Raceway Design

$volume = 0.081\ m^3$

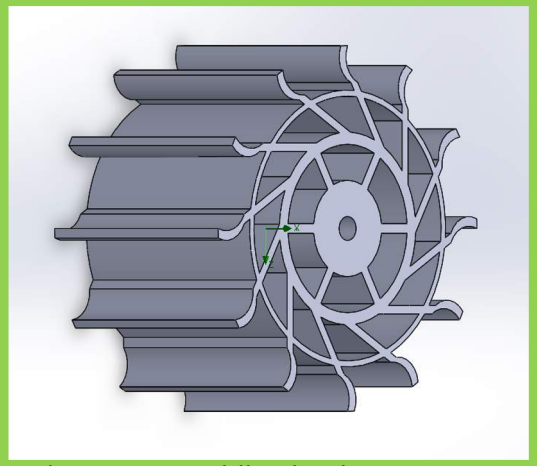


Developed by Cal Govoni and Jastine Tendi

Alternative Designs

- **Alternative Systems**
  - Closed Pond System
  - Biophotoreactor System
- **Paddlewheel Concept**
  - Materials
    - Aluminum
    - Stainless Steel
  - **Design**
    - Curved
    - Number of Paddle
- **Open Pond System**
  - Paddlewheel
  - Pump

Biophotoreactor



Alternative Paddlewheel Design

Open System Alternative

Analysis

$P_{hydraulic} = Q\rho g(h_B + h_S)$

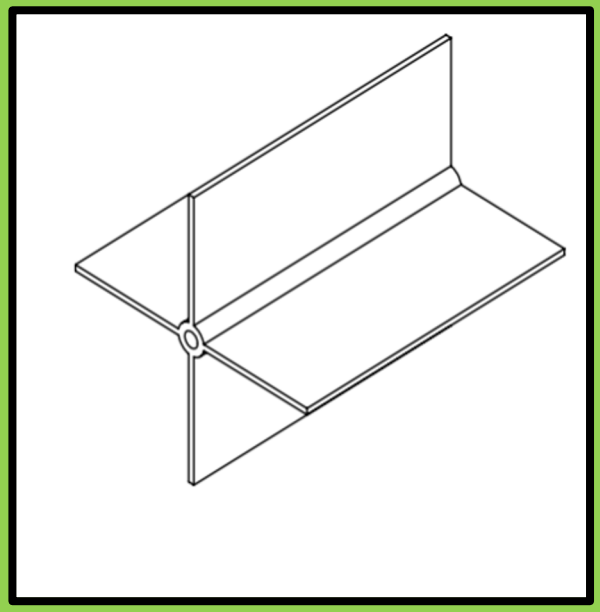
$P_{paddlewheel} = P_{hydraulic} / \eta$

$\eta = 0.4$ (assumed)

- Paddlewheel Power Requirement: 0.893 W

Q = Volumetric Flow Rate [m^3/s]
ρ = density [kg/m^3]
h_B= Head Loss in Bends [m]
h_S=Head Loss in Straightaways [m]
η = efficiency

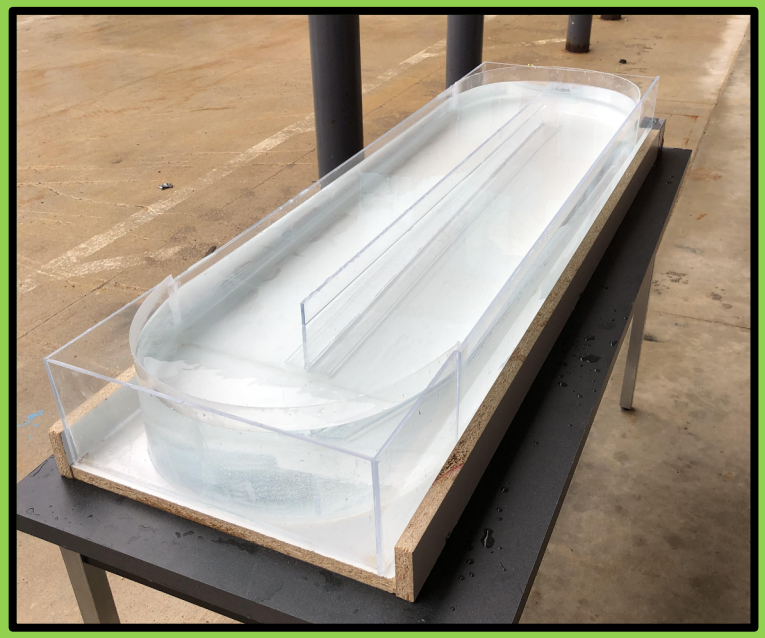
ATEC Algae Raceway Pond



Paddlewheel Design

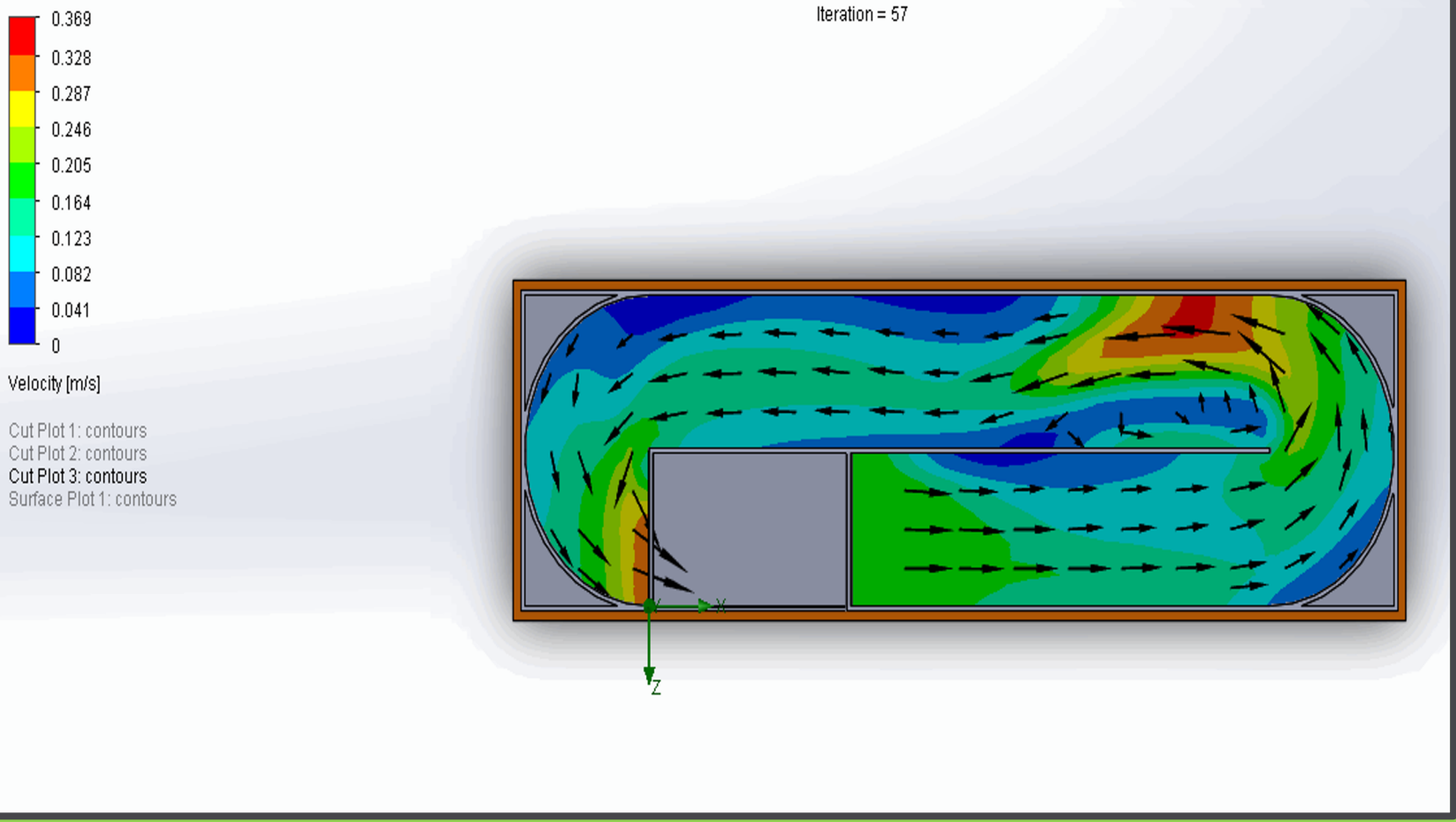
Testing Plan

- Our objective was to design a small raceway to compare to our analysis
- We were not able to finish building and perform testing due to COVID-19
- Plan was to measure velocity and power input into raceway to compare the expected power to the actual power



Unfinished Algae Raceway

Flow Simulation



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Project Specifics

CULTIVATION
- Equiptment
- Procedures
- Efficienty Growth

HARVESTING
- Flocculation
- Removal
- Energy Conversion

DRY and BURN

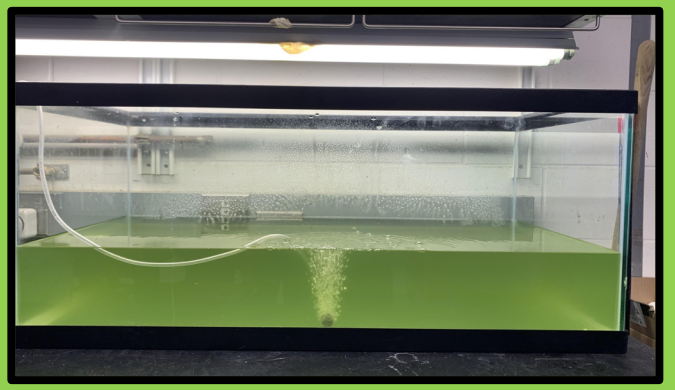
DRY and EXTRACT OIL

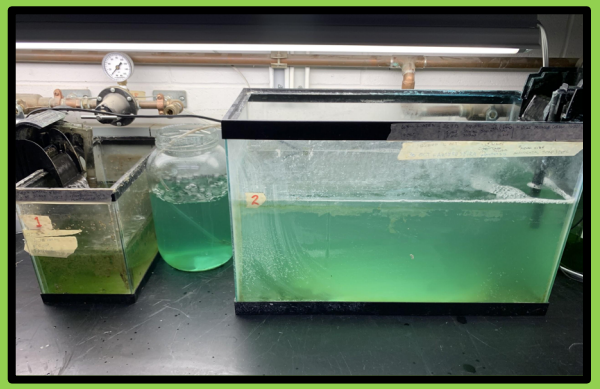
Ultimate Goal:

Generate Energy

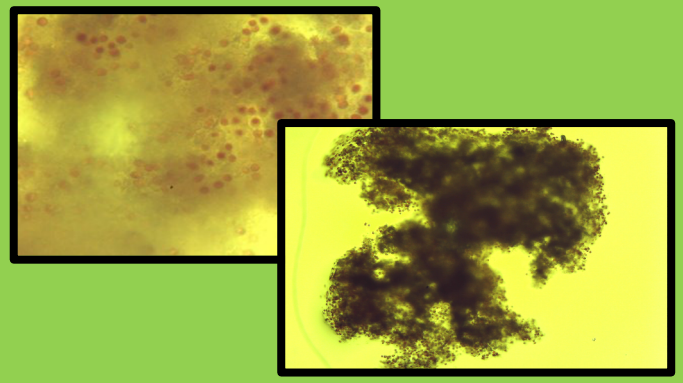
Growth Experimentation

- Mill Pond Sample
- Culture Growth Kits
- Growth Constants
  - Timed Fluorescent Lights
    - 10 hours on
    - 14 hours off
  - Aeration
  - Room temperature (70 F)
  - Nutrients: **F/2 Medium**
    - Sodium Nitrate
    - Monosodium Phosphate
    - Sodium Metasilicate Nonahydrate
    - Trace Metals
    - Vitamins

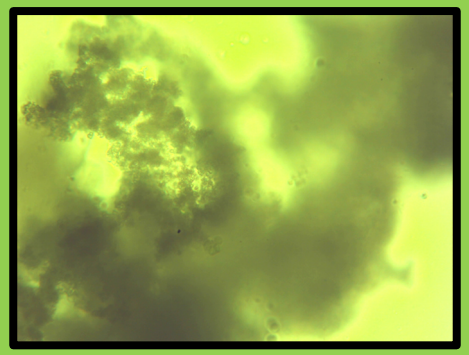




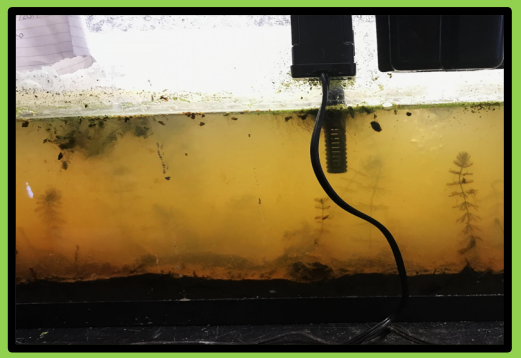
Alternative Species Investigated:



Porphyridium cruentum



Nannochloropsis oculata



Muskgrass

Species Chosen:

Nannochloropsis oculata

- Fast Growth Rate
- Local to NH
- High Amounts of Oil

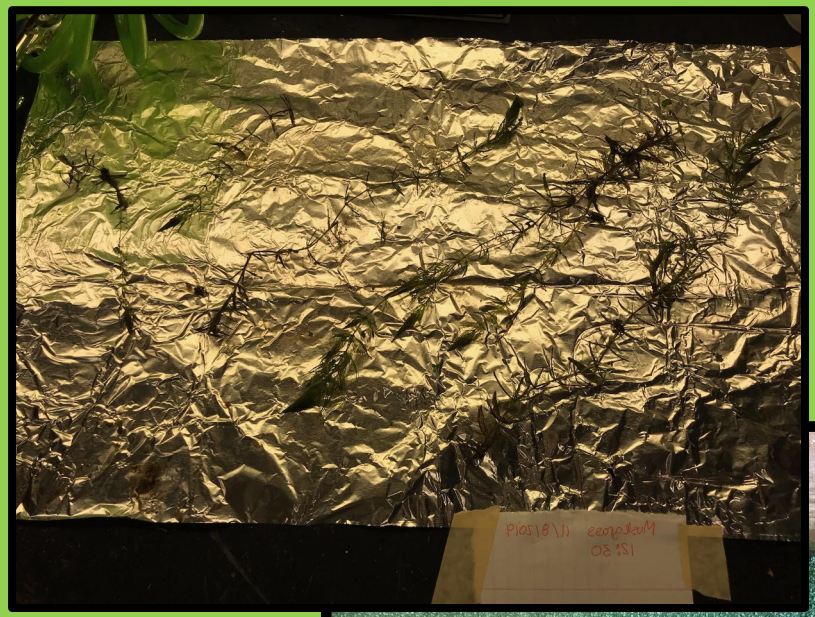
Flocculation

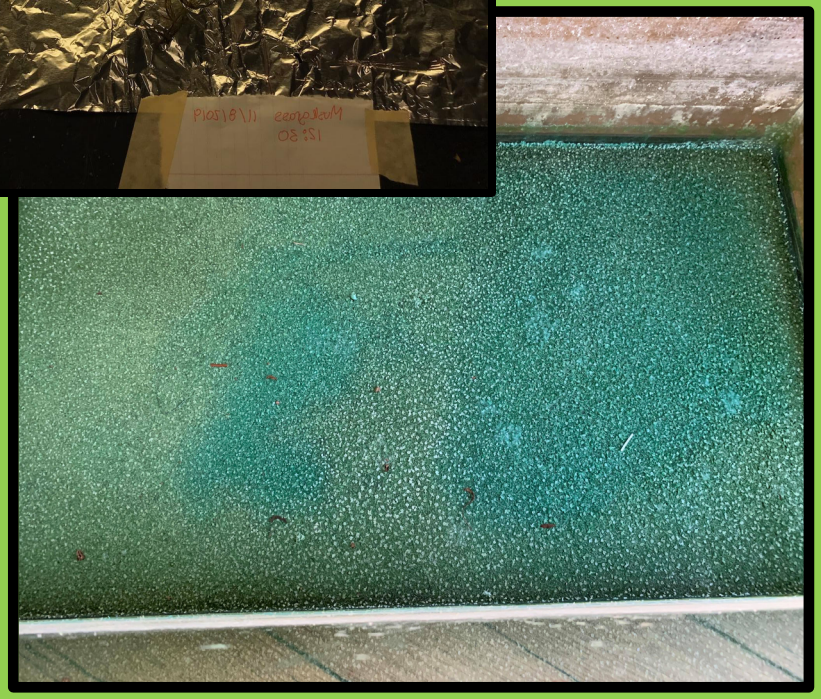
- Experiments with flocculation were limited due to COVID-19 Global Pandemic
- Aluminum Sulfate, Chitosan, Lowering the pH to 3-5
- Chitosan is the most environmentally friendly
- Dosages in past experiments are relatively low
- Prospective Flocculation tank following the growth tank to then run the algae through a filter and collect for oil extraction

Flocculation Demonstration

Drying Experimentation

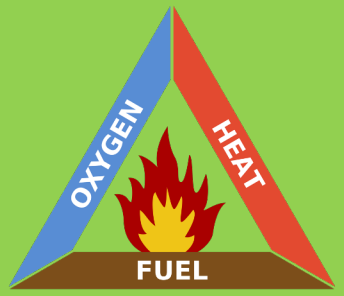
- Muskgrass harvested from Mill Pond Sample using aquarium net.
- Laid out on aluminum foil under LED light.
- Four trials conducted.

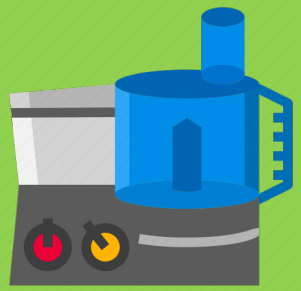
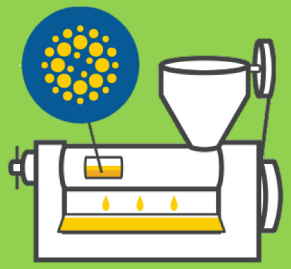




Drying Days	% Mass Loss
4	95
4	95
6	97
4	92

Energy Processing Methods

- Direct Combustion
  - 

- Oil Separation
  - Food Processor
    - 
  - Expeller Press
    - 
  - Chemical Separation
    - 

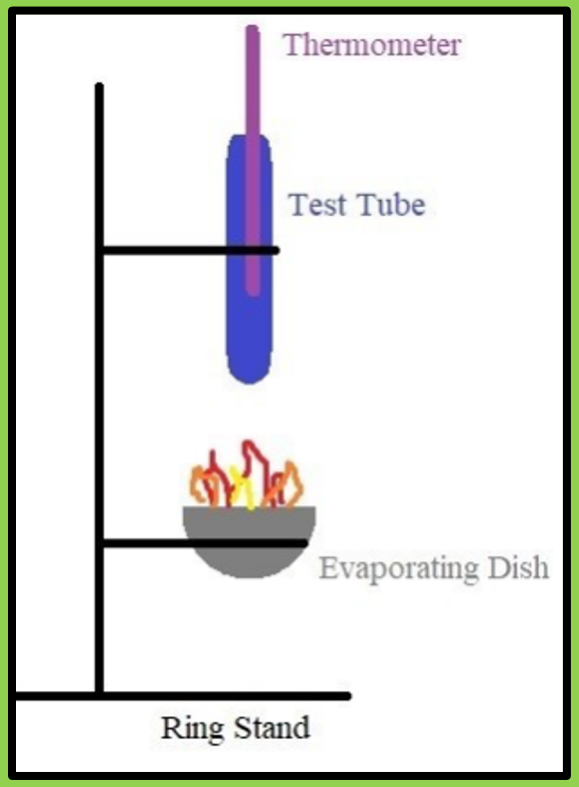
Direct Combustion

Experimental Procedure

- Determine the theoretical amount of heat which could be obtained from a set mass of dried algae.
- Involves burning a measured mass of algae directly under the test tube filled with water and measuring the change in water temperature.
- Relies on the Specific Heat Formula

$$Q = m \times c \times \Delta T$$

Q = amount of heat absorbed by the water in joules
m = mass of water in grams
c = specific heat capacity of water (4.186 joule/gram*°C)
ΔT = change in water temperature degrees Celsius



Experimental Combustion Diagram

Extracting Oil: Expeller Press

Common Expeller Press

Process:

1. Dry algae in direct sunlight for 48 hours
2. Grind algae to powder
3. Put algae in press
4. Collect oil

Using Hexane Solvent:

1. Hexane added to algae pulp in a ratio of 30g hexane to 50ml algae
2. Algae sit for 24 hours for separation to occur
3. Filter and collect oil

Feasibility:

- **Ease of Use**
  - Easily obtained
  - Might require manual cranking
- **Cost:**
  - assume $60/gallon hexane
  - assume $20 pestle and mortar
  - assume $200 expeller press
- **Efficiency:**
  - Press alone: 75% oil extracted
  - Press with hexane solvent addition: 95% oil extracted
- **Safety:**
  - Hexane is slightly toxic so safety masks should be worn

Extracting Oil: Food Processor

Process:

1. Blend algae let oil settle out
2. Add lye water/chemicals for transesterification
3. Add alcohol to solution
4. Mix and let settle overnight
5. Collect byproducts: glycerol, biodiesel
6. Produce: 1.5 Tbs oil per 1.5 cup of wet algae accumulating 1 tsp of biodiesel

Common Food Processor

Feasibility:

- Blender and electricity easily obtained
- Need: chemicals, alcohol

Cost:

- Blender: $50.00
- Electricity: $2 per 10 minutes blending
- Chemicals: potassium hydroxide 500g for $99.99;
- sodium hydroxide 2.5Kg for $39.95;
- Alcohol: methanol $50 per gallon; ethanol: $90/gal

Efficiency:

- 70-80% oil extraction

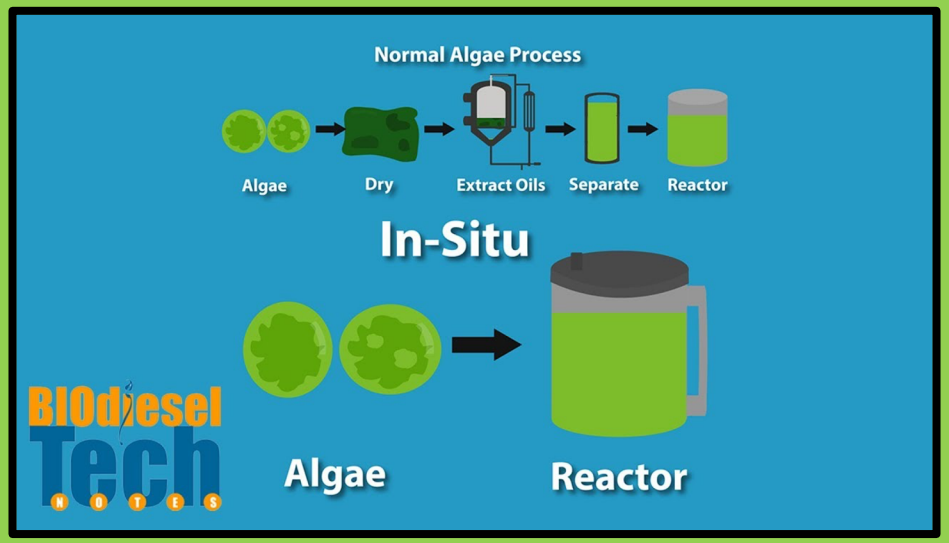
Safety:

- Take safety precautions to work with chemicals

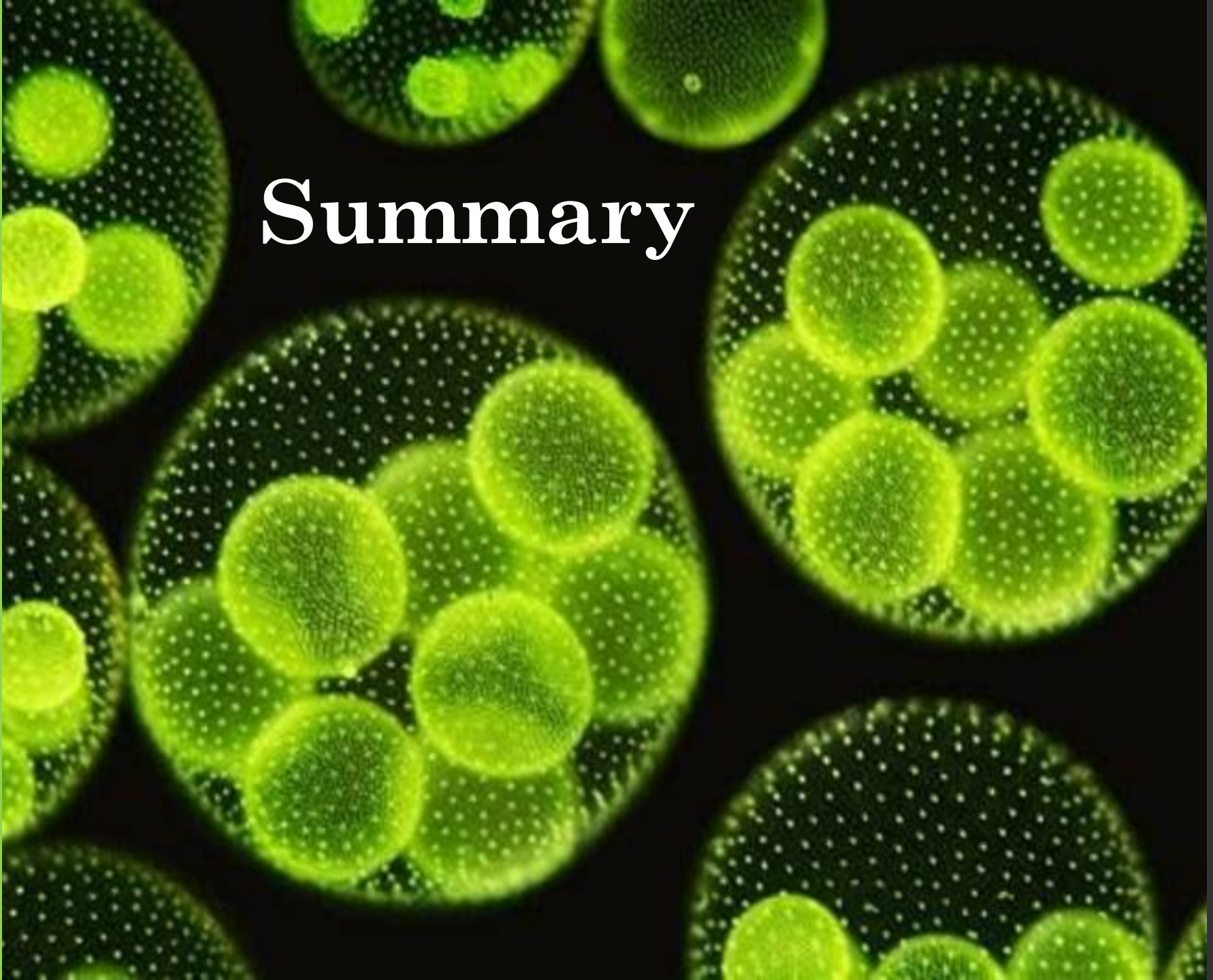
Chemical Oil Removal

Transesterification

- Shown to extract 90% to 95% oil
- Lab and materials were acquired to conduct chemical removal
- Replacing the glycerol molecule with an alcohol to create biodiesel
- Usually done on industrial scale to reduce cost



BIOdiesel Tech Oil Extraction Diagram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