INTERIM DESIGN REVIEW

Hydrogen from Microalgae

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Overview

- Project Scope & Objectives
- Background
- System Overview
- Procurement & Budget
- Challenges Faced & Lessons Learned
- Summary

Project Scope

- Design and maintain a photobioreactor system suitable for continuous operation and semi-continuous hydrogen production
- Objectives:
  - Design and calibrate an electronic hydrogen concentration measuring sensor
  - Develop automatic addition and extraction units
  - Create mechanical drawings of the bioreactor and all components

Project Evolution

- Collaboration with Universidade Federal do Paraná (UFPR)
- 2012-2013 Project:
  - Maximize algae concentration for use as biofuel
- 2013-2014 Project:
  - Design continuous system to produce biomass
  - Implement addition and extraction units
- 2014-2015 Project:
  - Design a continuous system to promote production hydrogen
  - Take on objectives from 2013-2014 project

Why is hydrogen so important?

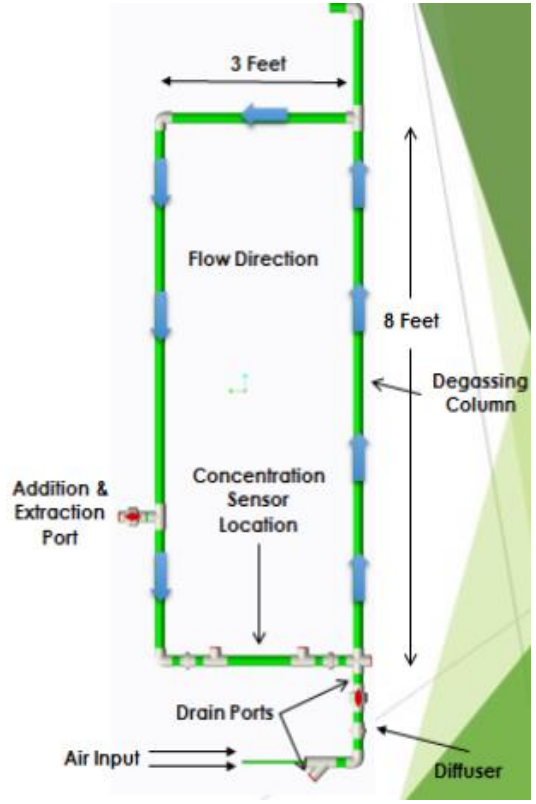
- Hydrogen is a renewable source of energy
  - Natural gas
  - No air pollutants or greenhouse gases
  - Domestic production
- Microalgae
  - Rapid growth rates
  - Uses raw materials

Hydrogen From Microalgae

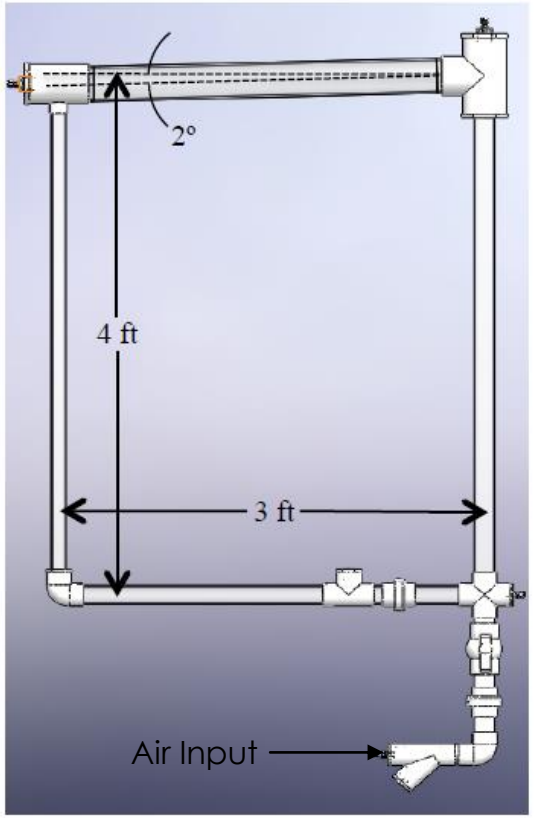
- Aerobic Respiration
  - Production of cellular energy involving oxygen
  - 15 more effective than anaerobic respiration
- Anaerobic respiration
  - Respiration in the absence of oxygen
  - Hydrogenase enzyme enables H_2 production
- Chlamydomonas reinhardtii (strain CC-125)
  - Mutant strain
  - Displayed increased H_2 production
- Scenedesmus sp.

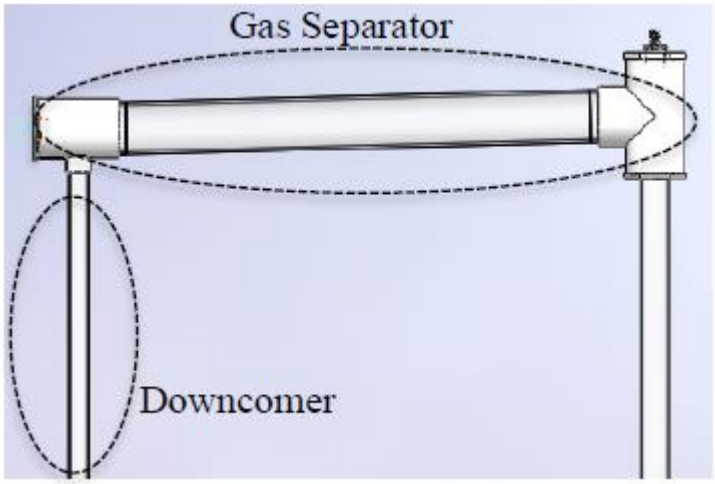
Past & Current Design

2013-2014 Design

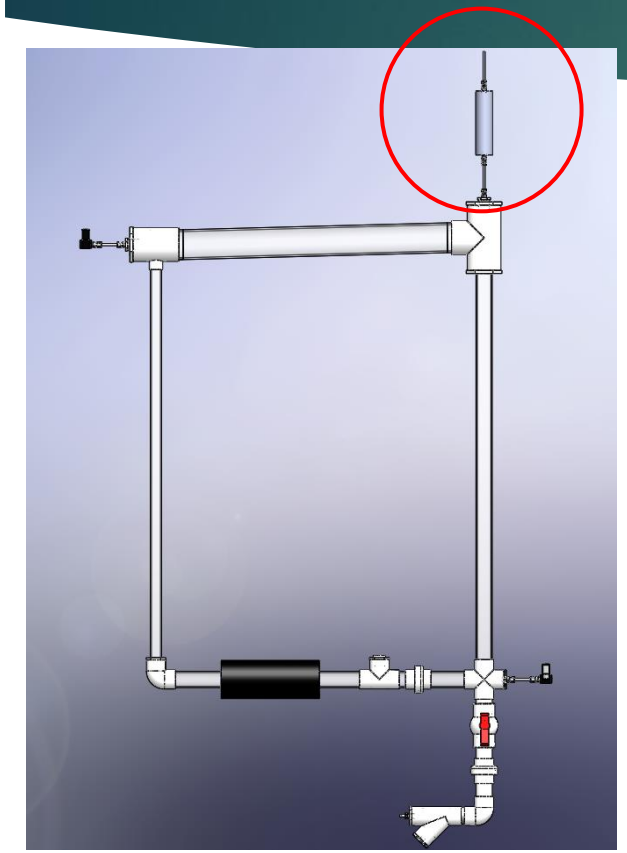


Current Design





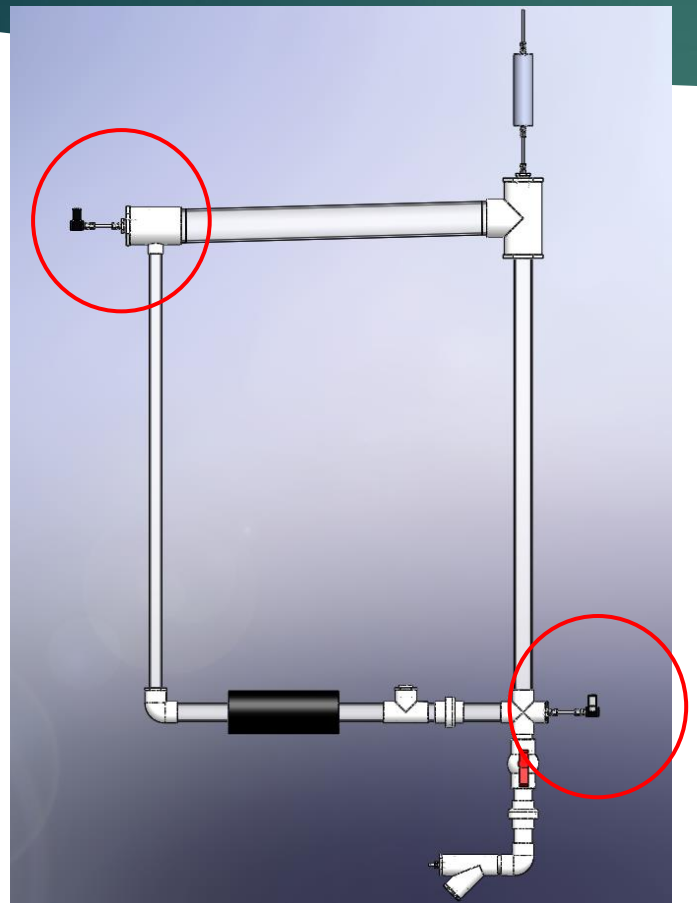
Components



H_2 PURIFIER

- Removal of O_2 and other organic impurities
- Minimum working pressure drop, 0.3 psi
- Removes less than 50 ppb
- 1/4 " Compression fittings
- Disposable at 1200 cubic ft. of standard grade hydrogen gas

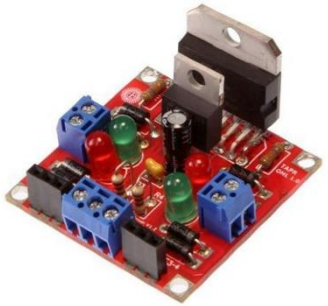
Components



Addition/Extraction Ports

- Gravity fed system
- Works with 2-12 VDC, 450 mA, normally closed solenoid valves
- Motor Driver used
- C_v = 0.23
- Fill time:

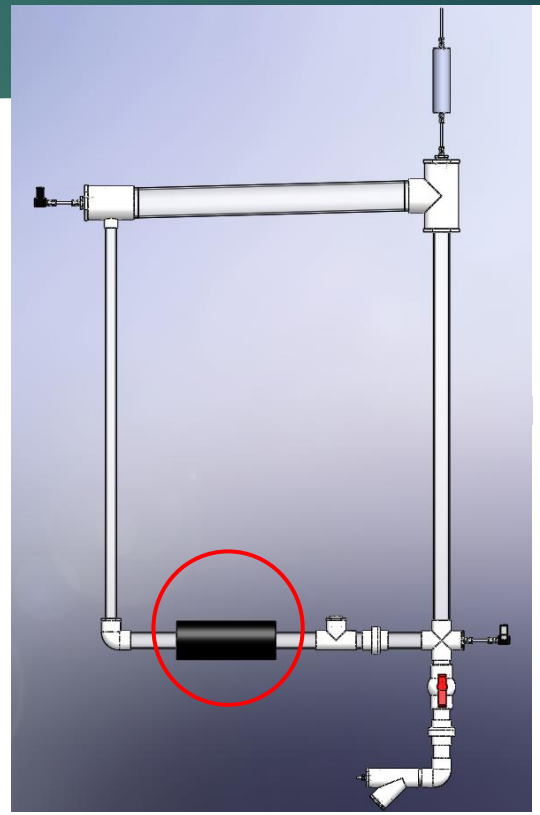
$$Q = C_v\sqrt{\frac{\Delta P}{SG}} \approx 7\ min$$

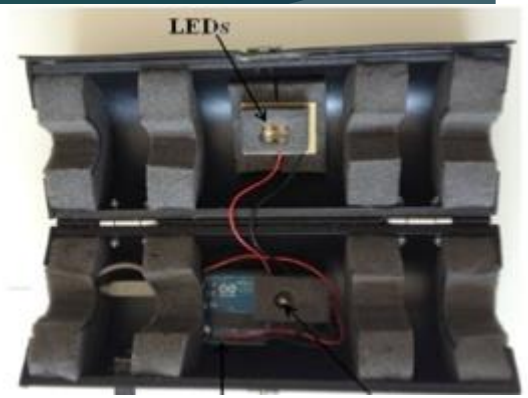


Components

Concentration Sensor

- Master controller of photobioreactor
- Designed and built by 2012-2013 Team 7 Senior team
- Works with 4-LEDs and a Light Dependent Resistor (LDR)
- Increase in concentration reduces resistance and voltage through LDR
- Change in voltage converted to 8-bit value
- Concentration reading taken roughly every 30 seconds daily

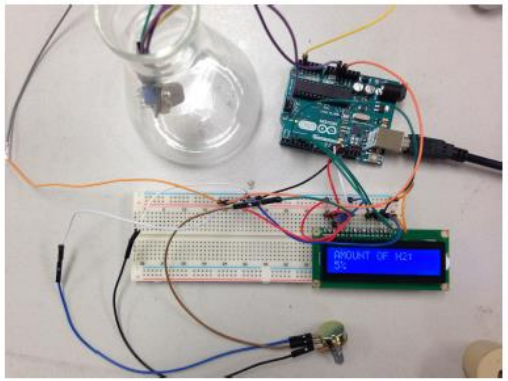




Components

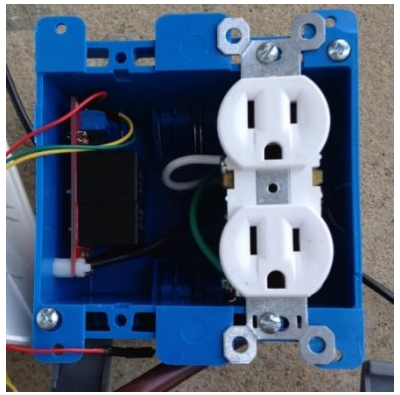
H_2 Sensor

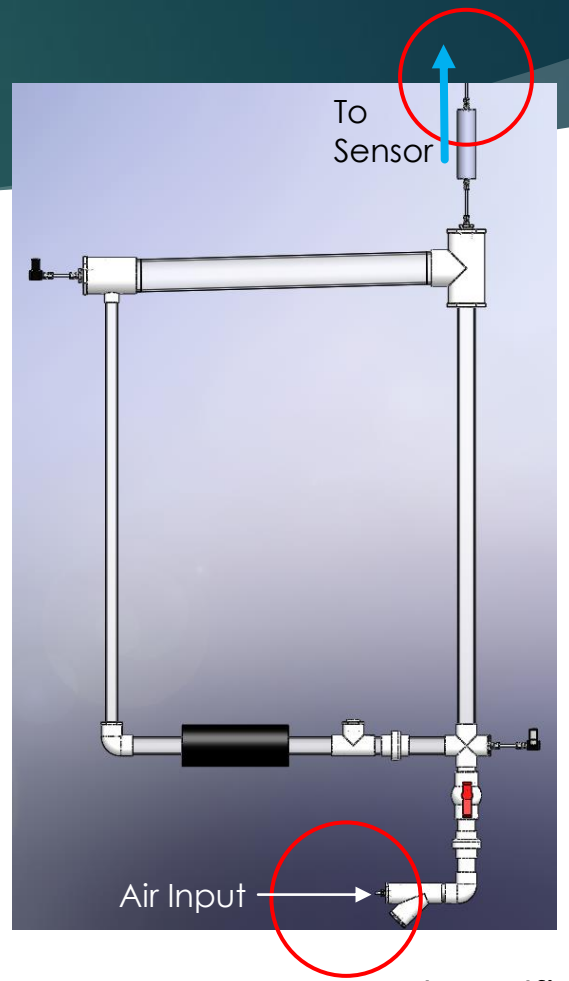
- Original Prototype tested in Brazil (UFPR)
- Components include
  - MQ-8 Gas Sensor
  - Arduino Uno Microcontroller
- Measures % concentration down to 100 ppm
- LCD display added for improved readout



Relay

- Function as on/off switch for air compressor
- JQX – 15F solid state relay
  - Control voltage = 5 V
  - Control amperage = 185 mA
  - Rated load of 220 VAC, 20 A
- Controlled through Arduino Uno board





Fluid and Reactor Analysis

Photobioreactor Analysis

- Lateral Surface Area to Volume Ratio
  - The higher the value the better light utilization for algae

$$\frac{A}{V} = \frac{2\pi rl}{\pi r^2 l} = \frac{2}{r} = \frac{4}{d}$$ **= 2.67 in^{-1}**

- Cross Sectional Area Ratio of Down-comer to Riser
  - Important for large scale implementation
  - Shows dimensionless parameter useful to retain fluid flow properties

$$\frac{Ad}{Ar} = \frac{\pi r_d^2}{\pi r_r^2} = \frac{r_d^2}{r_r^2}$$ **= 0.36**

Fluid Analysis

- Superfical Gas Bubble Velocity
  - Parameter used to brevent break-up of algae cell

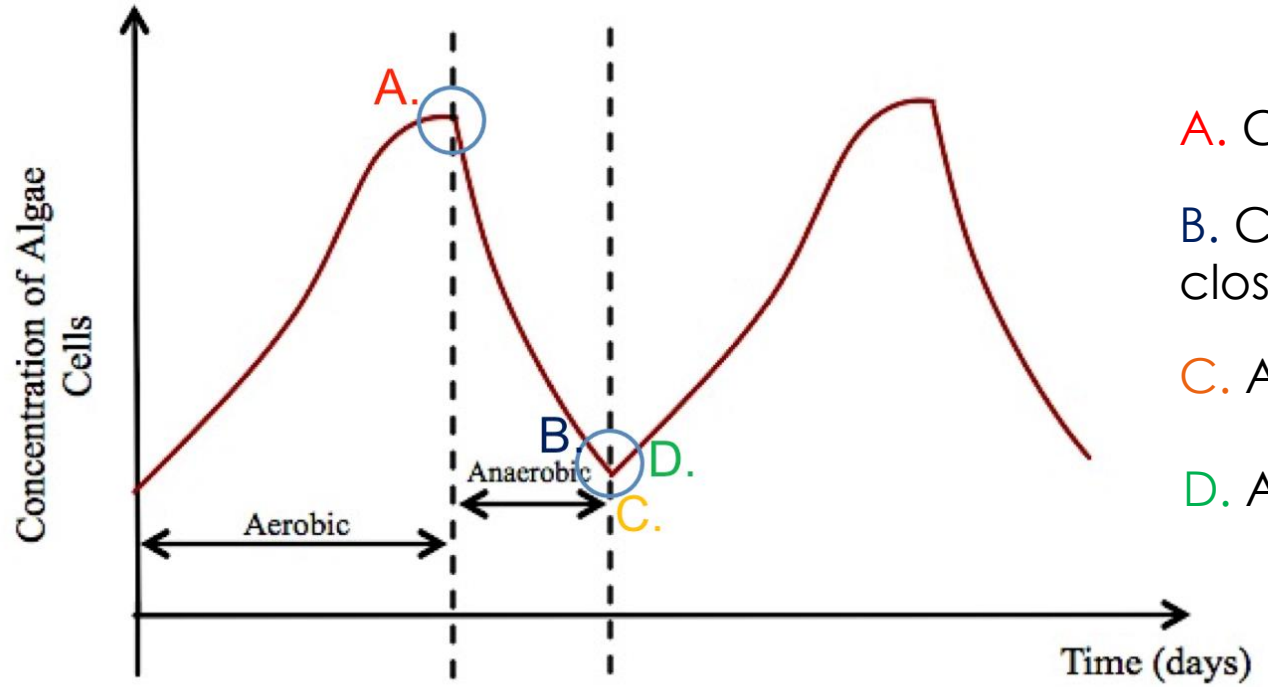
$$v_{(shear)} = \sqrt{\frac{\tau}{\rho}}$$

  - For *Chlamydomonas reinhardtii,* tau is 0.01 Pa
  - V_{shear} is 1/10th mean flow velocity: V_{gas} **≈ 1.25 in/s**
- Volume Flow Rate of Air Input
  - Used to provide air pump volumetric flow rat

$$v_{gas} = \dot{V}_g / A_r$$

  - **0.0764 cfm**

System Function



A. C_{max}: Air off → Relay switches OFF.

B. C_{min} : Extraction→ Valve opens until empty → Valve closes.

C. Addition: Valve opens until full → Valve Closes.

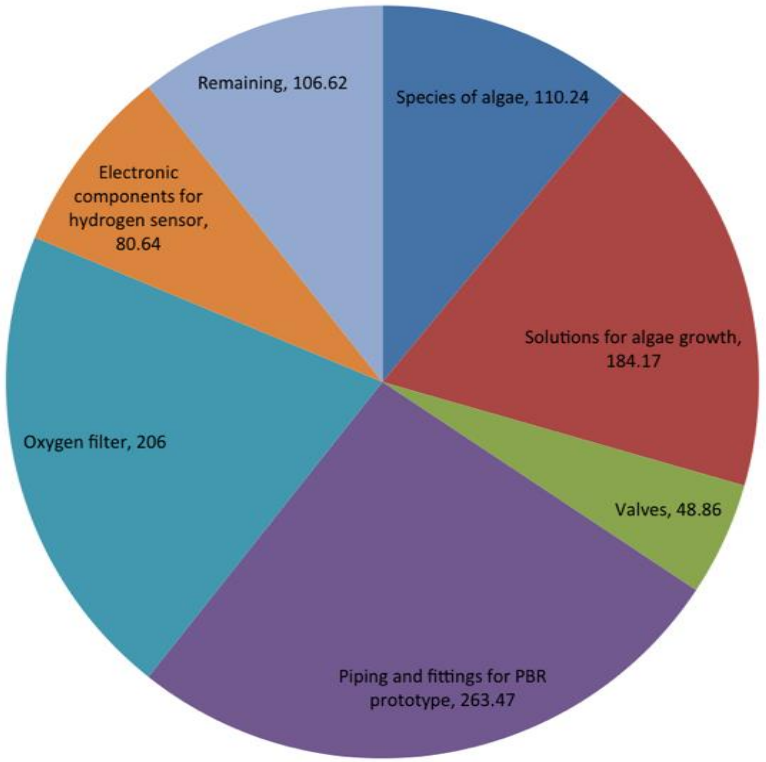
D. Air ON: Relay switches pump on.

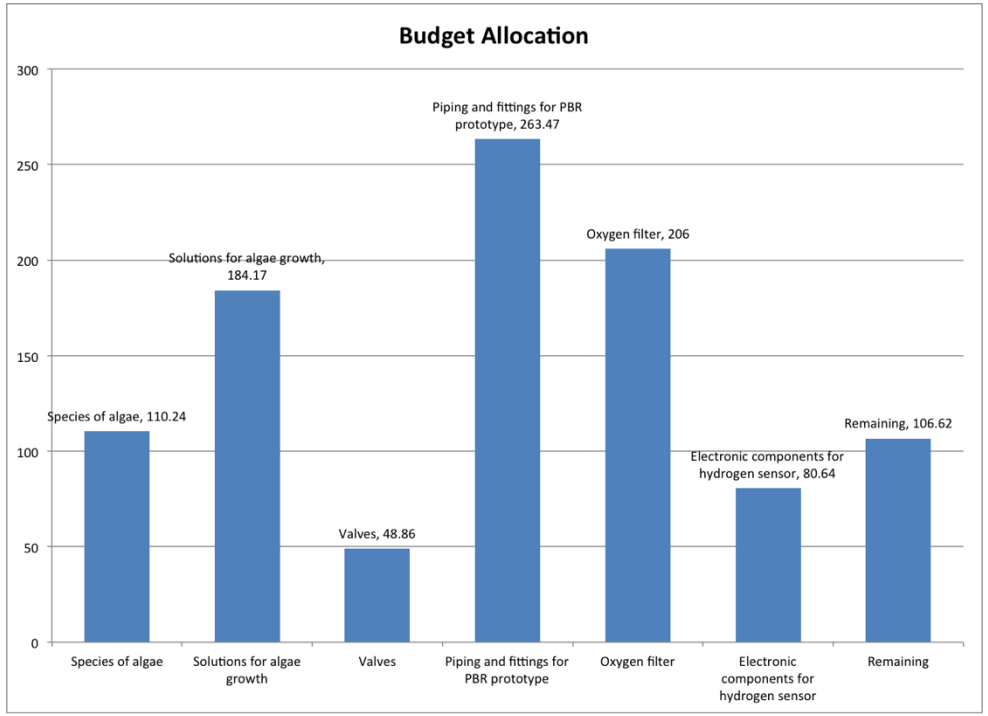
Prototype

Procurement

- Team procured items to construct:
  - Photobioreactor with stand
  - Hydrogen mass concentration sensor
  - Relay for air compressor
  - Addition and extraction solenoid valves
  - Microalgae lab experiments
- Purchased through McMaster-Carr, STC Valves, Sparkfun, and Carolina Biological Supply
- Items procured for a **total cost of $812.55**

Budget


Remaining, 106.62
Species of algae, 110.24
Electronic components for hydrogen sensor, 80.64
Solutions for algae growth, 184.17
Oxygen filter, 206
Valves, 48.86
Piping and fittings for PBR prototype, 263.47


Budget Allocation
300
250
200
150
100
50
0
Species of algae, 110.24
Solutions for algae growth, 184.17
Valves, 48.86
Piping and fittings for PBR prototype, 263.47
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Remaining, 106.62
Species of algae
Solutions for algae growth
Valves
Piping and fittings for PBR prototype
Oxygen filter
Electronic components for hydrogen sensor
Remaining

Challenges Faced & Lessons Learned

- Challenges:
  - Maintaining continuous communication between team members and advisors
  - Ordering parts
  - Implementation of components from past projects (2012-2013 and 2013-2014)
- Lessons Learned:
  - Work efficiently within a group
  - Time management
  - Practicing professionalism with colleagues and superiors

Future Recommendations (2015-2016)

- Cultivation of microalgae for production of hydrogen
- Use an air pump
- Incorporate more sensors
  - Temperature
  - Pressure
- Additional valves
  - 1-way valve for fluid backup to air pump
- Veins and fins
  - Promotes better flow

Summary

- Photobioreactor and stand have been assembled
- Addition/Extraction units, relay, pump, and concentration sensor have been successfully implemented and tested on the photobioreactor
- Hydrogen gas sensor has been calibrated and tested
- Under budget: $812.55 out of $1,000

Questions/Comments?