Recreate Energy: Energy for a Brighter Future

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Introduction

- Global reliance on crude oil creates a need for alternative sources
- Recreate Energy's goal is to turn algae into crude oil through hydrothermal liquefaction
- Already completed extensive research into the best micro-algae and the system to suit its needs
- Our team has 3 subteams: heating and cooling, electronic box, and electroflocculation

Existing Solutions

- Continuous Flow Reactor System at the Pacific Northwest National Laboratory
  - High temperature and pressure converts algae to crude oil with byproducts
  - Crude oil can be converted to gasoline or aviation fuel
  - Uses wet algae to avoid drying process and related costs
- Saltgae Project at Camporosso, Italy
  - Spirulina algae collected from wastewater is used to produce crude oils and other byproducts
  - Spirulina algae absorbs pollutants such as nitrates to serve as a dual purpose and purify the water

Figure A: The set up Lab at Camorosso have for their purification process

Figure B: Pacific Northwest National Laboratory's bioreactor set-up

NOTE: All designs shown are under the jurisdiction of RECREATE ENERGY under NDA

Heating and Cooling Subteam

Santiago Buitron

Objective

- Design and Fabricate a Heating and Cooling Thermoelectric system to properly optimize algae growth conditions

Challenge

- The design must be cost effective, weather resistant, and a small-scale system
- The Heating and Cooling system will contain Peltier Modules
- System must be controlled via Arduino

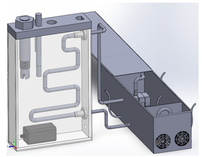


Figure 1: Outer view of the heating and cooling system

Key Elements

- Box is made of 3003 Aluminum alloy
- All piping is made of PVC tubing with the exception of copper tubing inside the bioreactor
- All Water pumps submerged in reservoir section.

Future Improvements

- Expand to cool; either adding fan or liquid cooling

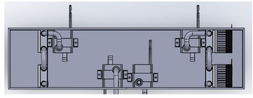


Figure 2: Inner View of the heating and cooling system

Impact on Society

- Optimal temperature conditions will allow algae to yield a consistent biofuel production.

Safety

- The box is separated by 3 sections by welded sheet metal to prevent water leakage to the electronics.

Budget

- The whole system including the three sub-teams should not exceed about $1000, so our reservoir system should be around a third of that (~$300)

Performance

- Can heat water from 25 to 28 degrees celsius within a minute and 15 seconds on average, when operating at 20 V, 7 A, and 140 W.

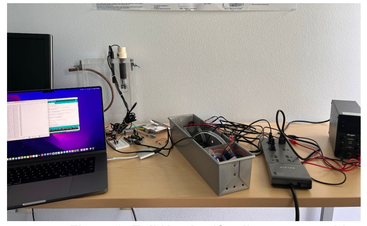


Figure 3: Full Heating/Cooling system with running code

Electroflocculation System Subteam

Rene Valencia
Shaun Kim

Objective

Create a system that can pump algae and water solution in, separate algae from water, and create an algae slush byproduct that can be harvested.

Challenges

- Weather resistant, small scale, and cost effective design
- Hold 1L of fluid in tank
- Separate biomass through electrolysis
- Easy removal of two byproducts
- Compatible with Arduino

Key Elements

- Acrylic sheets for tank and electrode case
- 3 Aluminium-6101 and 3 Carbon electrode configuration to achieve electrolysis
- Tube brush and motor to separate algae slush
- Slanted floor to allow wastewater to exit
- Solenoids and water pumps to move fluid

Performance

- Simulation of flow analysis showed successful design
- Tank is able to push water in, hold 1L of liquid, and remove wastewater
- Electrolysis is successful. It was tested by producing H_2 gas
- Brush successfully turns on and scrapes against separation wall

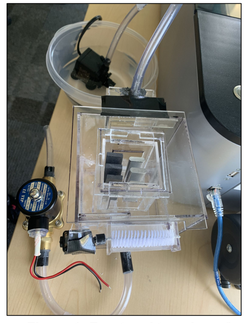


Figure 1: Front and top view of prototype.

Safety

- Electronics are distanced from liquid
- Relatively isolated input substance from outside environment

Future Improvements

- Integration of solenoid that uses less voltage to run (current ~8-12 V)
- Automation of system
- Testing electrolysis with algae (only tested with water so far)

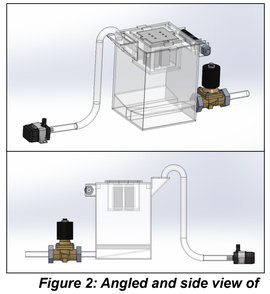


Figure 2: Angled and side view of CAD model

Bill of Materials

Item Description	Quantity	Price per Item
Extruded Acrylic Sheet (400 X 330 X 3 mm)	2	$8.05
6101 Aluminum Bar (¼ X ¾ X 5 in)	2	$13.23
Flat Carbon Electrode	3	$12.77
DC 1.5-3V Mini Electric Motor	1	$6.99
Drinking Straw Brush Pipe (8in rod, 2.5 X 0.7 in brush)	1	$5.99
WELD-ON 4 Acrylic Adhesive [4 Oz]	1	$19.35
20 pack of Alligator clips with wires	1	$7.99
10 ft long Vinyl Tubing [5/16 ID, 7/16 OD in]	1	$7.99
5V 4 Channel Relay Optocoupler Isolation	1	$8.99
Brass normally closed electric solenoid valve [1/2" female port] 12V	2	$21.99
10-piece pack Plastic Hose Barb Fitting Mender Joint [5/16" x 5/16"]	1	$10.99
12 piece Metals Brass Pipe Fitting (Male and Female Thread Pipe) [1/2" x 1/2"]	1	$22.79
Cold-Weld Cold-Weld Steel Reinforced Epoxy [2 oz.]	1	$5.13
Imagitarium Power Head water pump	1	$24.99
TOTAL	**$236.22**	

Electronic Box Subteam

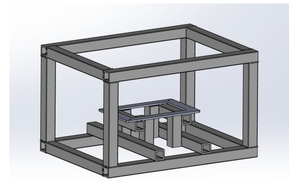
Erica Stoll

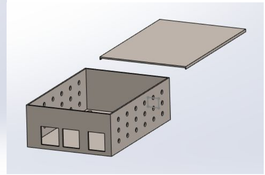
Overview:

Case for the electronics to protect from the elements and physical abuse, while still able to receive data from sensors and transmit information to databases without overheating the internal electronics

Attributes:

- Self-cooling case for the Arduino, Raspberry Pi, and PCB
- Air vents to maximize airflow while minimizing moisture entry
- Slide panel for easy access to electronics
- Ports for all connections (subject to change)
- Keeps the Arduino at recommended operating temperature
- Steel frame to withstand blunt force
- Impact resistant mesh that allows air flow
- Solid top panel to prevent direct weather damage (sun, rain, etc.)
- Mounting platform to mount cases together

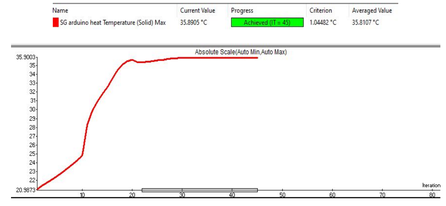




Bill of Materials:

Item Description	Quantity	Price per item
22-Gauge Plain Sheet Metal	2	$7.51
1/2in Plain Steel Square Tube	2	$13.83
Steel Reinforced Epoxy	1	$14.79
Stainless Steel Woven Wire Mesh	1	$11.77
18-8 Stainless Steel Phillips Screw 0-80 Thread	1	$6.30
18-8 Stainless Steel Hex Nut 0-80 Thread	1	$7.43
Rust Inhibitor Black Paint	1	$13.25
Total		**$96.22**

Thermal Analysis



- Arduino output at 5 Volts
- Natural Convection at 25 °C
- Average temperature running at 35.8 °C
- Recommended operating range is between -25 °C and 75°C

Manufacturing:

- Not qualified for welding -> used epoxy instead to save on cost
- Can operate without PCB hat, but should install one
- PCB minimizes manufacturing costs
- Inner case made of aluminum for its thermal conductive properties
- Outer case made of steel for its sturdy properties

Design Flaws:

- Water resistant but not waterproof; will not be able to function in heavy rain and flooding
- May still experience rusting issues despite the rust inhibitor

References:

1. Cappai, Lorenzo, et al. "Simulation-Based Study of the Energy Requirements Linked to the Temperature Control of Micro-Algae Culture in Outdoor Photobioreactors." Engineering Archive, 2017, https://doi.org/10.31224/osf.io/753nx.
2. Douglas, Elliot, et al. Process development for hydrothermal liquefaction of algae feedstocks in a continuous-flow reactor. Algal Research. Volume 2, Issue 4. 2013. Pg 445-454. ISSN 2211-9264. https://doi.org/10.1016/j.algal.2013.08.005.
3. Fourneris, Cyril, and Katy Dartford. "How Microalgae Can Treat Wastewater and Make It a Valuable Resource." Euronews, 30 Aug. 2019, https://www.euronews.com/next/2019/08/26/how-microalgae-can-treat-wastewater-and-turn-it-into-a-valuable-resource.
4. Garcia, M.P. & Cosley, Michael. (2004). "Ambient air cooling of electronics in an outdoor environment." INTELEC, International Telecommunications Energy Conference (Proceedings). 437 - 441. 10.1109/INTLEC.2004.1401505.
5. López-Rosales, Lorenzo, et al.
6. "Characterization of bubble column photobioreactors for shear-sensitive microalgae culture." Bioresource Technology. Volume 275. 2019. Pages 1-9. ISSN 0960-8524. https://doi.org/10.1016/j.biortech.2018.12.009.
7. Rickey, Tom. "Algae to Crude Oil: Million-Year Natural Process Takes Minutes in the Lab." Pacific Northwest National Laboratory, 1 Oct. 2017, https://www.pnnl.gov/news/release.aspx?id=1029.
8. Robinson, Vivian. 1999. Electroflocculation in the Treatment of Polluted Water. Australian Water and Wastewater Association. November 1999. Pg. 181-188. https://www.researchgate.net/publication/265990355_Electroflocculation_in_the_Treatment_of_Polluted_Water
9. Sanchez-Galvis, Edwin, et al. An Innovative Low-Cost Equipment for Electro-Concentration of Microalgal Biomass. Appl. Sci. 2020, 10, 4841. https://doi.org/10.3390/app10144841
10. Saukon Kamalul Husna, Anif, et al. "Air Temperature Control System in Silent Generator Box." JEEE-U (Journal of Electrical and Electronic Engineering-UMSIDA), vol. 5, no. 2, 2021, pp. 165–174., https://doi.org/10.21070/jeeeu.v5i2.1556.
11. Wang, Baowei, et al. "Development of Novel Bioreactor Control Systems Based on Smart Sensors and Actuators." Frontiers in Bioengineering and Biotechnology. Volume 8. 2020. ISSN 2296-4185. https://www.frontiersin.org/article/10.3389/fbioe.2020.00007