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Fish Pond Aerator Energy Source

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Fish-Pond Aerator Design Showcase

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Faculty Mentor: Aram Agajanian

Acknowledgements

- AgInno Intitute
  - Eric Johnson
  - Don Roe
- Olivet Nazarene University
  - Dr. Aram Agajanian
  - Dr. Joe Schroeder
  - Kristie Schultz

Roles

- Matt George
  - Mechanical & electrical engineering
  - Project organizer/communication facilitator
- Luke Johnson
  - Mechanical engineering
  - Focus on the mechanical aspects of re-designed prototype
- Ben Ridler
  - Electrical & computer engineering
  - Focus on the electrical aspects of harvested energy for the aerator

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Overview

- Sponsor Background
- Problem Description
- Design Alternatives
- Proposed Design
- Final Detailed Design
- Design Validation
- Recommendations
- Questions

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Sponsor Background

AgInno Institute

- Where: Chisec, Guatemala
- What: Missions Organization focused in Agricultural Work
  - Tilapia Fish-Ponds

El Puente

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Sponsor Background

- AgInno Institute

  "...we are passionate about reaching people for Jesus by making real differences in their lives via improved and more healthy living conditions, access to water, improved agriculture techniques, and equipping them to provide food and income for themselves and their families."

  https://www.aginno.org/

AgInno ABET Engineering Accreditation Commission

Problem Description

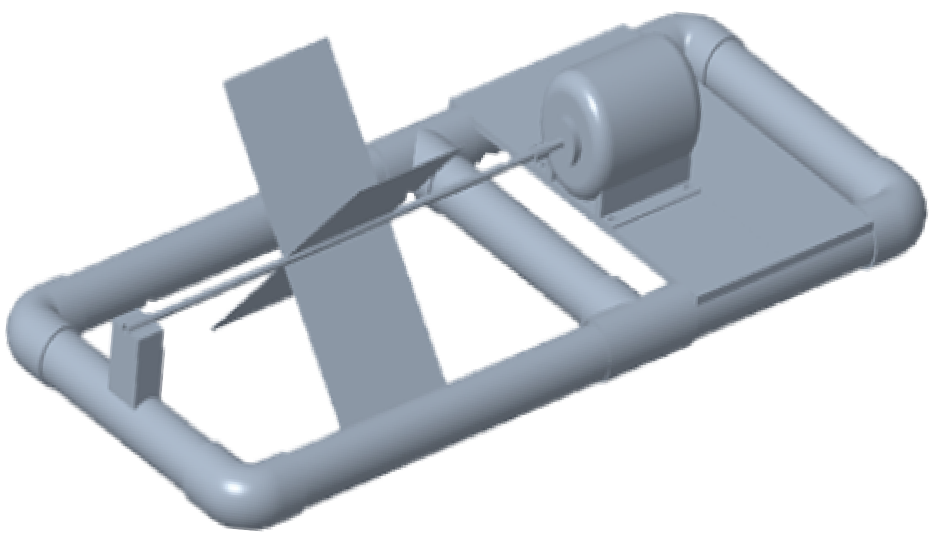
- **Previous Design Teams**
  - Dense Tilapia fish-ponds resulted in depleted oxygen content
  - Previous teams designed an aerator to pump oxygen into the water
  - Aerator required too much power from the power grid

Problem Description

- **Need Statement**
  - Design an aerator system prototype that uses harvested energy and renewable energy to oxygenate the fish-pond
  - Harvested energy and renewable energy provides the possibility of monetary profit and community growth

Aerator

Aerator Creo Model



Aerator Prototype used in Guatemala

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Problem Description

- Design Objectives
  - Efficiently Aerate the Pond
    - (SAE: [kg O2]/kWh)
  - Operate Predominately from Harvested Energy
    - (hours of independent operation/day)
  - Minimize Overhead Cost of Aerator
  - Design w/ Readily Available Materials in Guatemala
  - Withstand Environmental Conditions

Problem Description

- Functional Requirements
  - Aerate a Man-Made Tilapia Pond
  - Harvest and Store Renewable Energy
  - Float and Anchor in the Pond
  - Run Continuously

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Problem Description

- Design Constraints
  - Maintain Aeration @ 0.5-0.7 mg O2/L
  - SAE ≥ 2
    - (SAE: [kg O2]/kWh)
  - Operation Costs < Expected Returns
  - Components last a minimum of one harvesting season
  - Electrical components are protected for safety

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Deliverables

- A cheap and efficient design with detailed specifications
- Reliable data, linked to prototype configuration
- Report of electrical system (solar panels, battery, capacitor, all connections and seals)

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Verification & Test Plan

Operation	Requirement	Testing Means	Pass/Fail
Aeration	$0.5 \le x \le 0.7$ mg O_2/[L H_2O]	O_2 meter	Pass/Fail
SAE	SAE > 2 [kg•O_2/kWh]	O_2 meter/watt-meter	Pass/Fail
Energy Harvesting	Exceeds required power capacity of aerator	Watt-meter	Pass/Fail
Energy Storage	Availability and cycle life	Battery specifications	Pass/Fail
Aerator Buoyancy	Aerator & paddle design visibly floats in pond	Visual inspection	Pass/Fail
Aerator Anchoring	Aerator is fixed in pond	Visual inspection	Pass/Fail
Weatherproof & Robust	Aerator system is weather/waterproof	Demonstration	Pass/Fail
Accessible Supplies	Purchased/found in Guatemala	Geographical	Pass/Fail
Cost	Expenses < Profits	Estimated Cost Analysis	Pass/Fail

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Design Alternatives

- Renewable Energy

Wind Turbine

Water Turbine

Solar Panel

Design Selection

- Renewable Energy Design Matrix

Design Alternative	Source Availability	Energy Harvested	Cost	Energy Storage	Durable	Material Availability	Total
Weight	*8*	*8*	*6*	*5*	*3*	*2*	
Wind	1	3	1	2	2	1	56
Running Water	1	2	3	2	1	2	59
Solar	3	1	3	2	3	3	**75**

Scale: 1 to 3

1: Least preferred

3: Most preferred

Design Alternatives

- Motor Configuration

AC Motor

DC Motor

Design Selection

- AC/DC Motor Configuration Design matrix

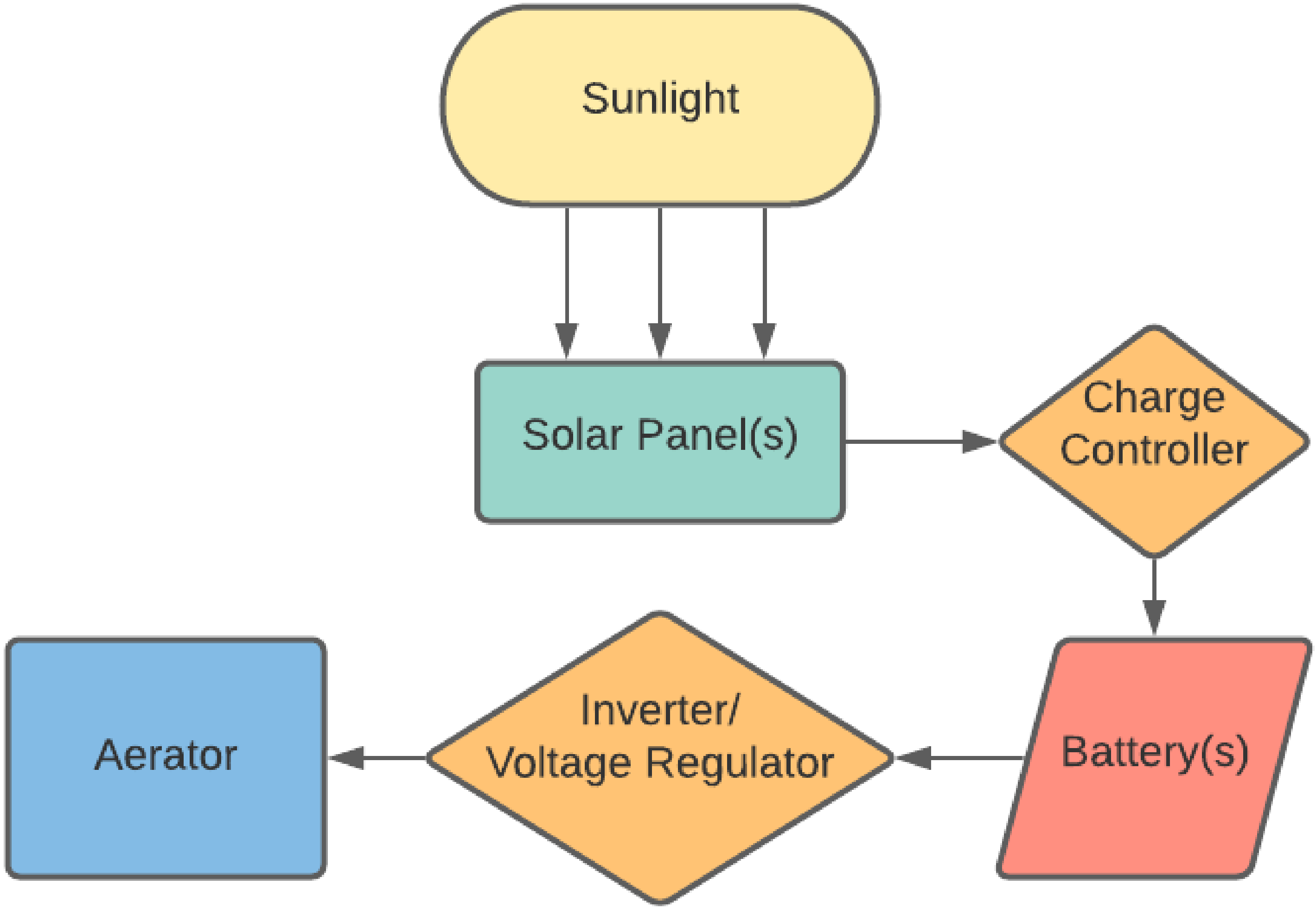
Design Alternative	Cost	Material Availability	High Torque	Precision	Diverse Options	Total
Weight	*10*	*8*	*3*	*3*	*5*	
AC Motor	2	2	2	1	2	**55**
DC Motor	1	1	1	2	1	32

Scale: 1 to 2

1: Least preferred

2: Most preferred

Proposed Design



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Proposed Design

- Renewable Energy Source: Solar
- Motor Configuration: AC
- Energy Storage: Lead Acid
- Charge Controller: MPPT
- AC Inverter: Pure Sine

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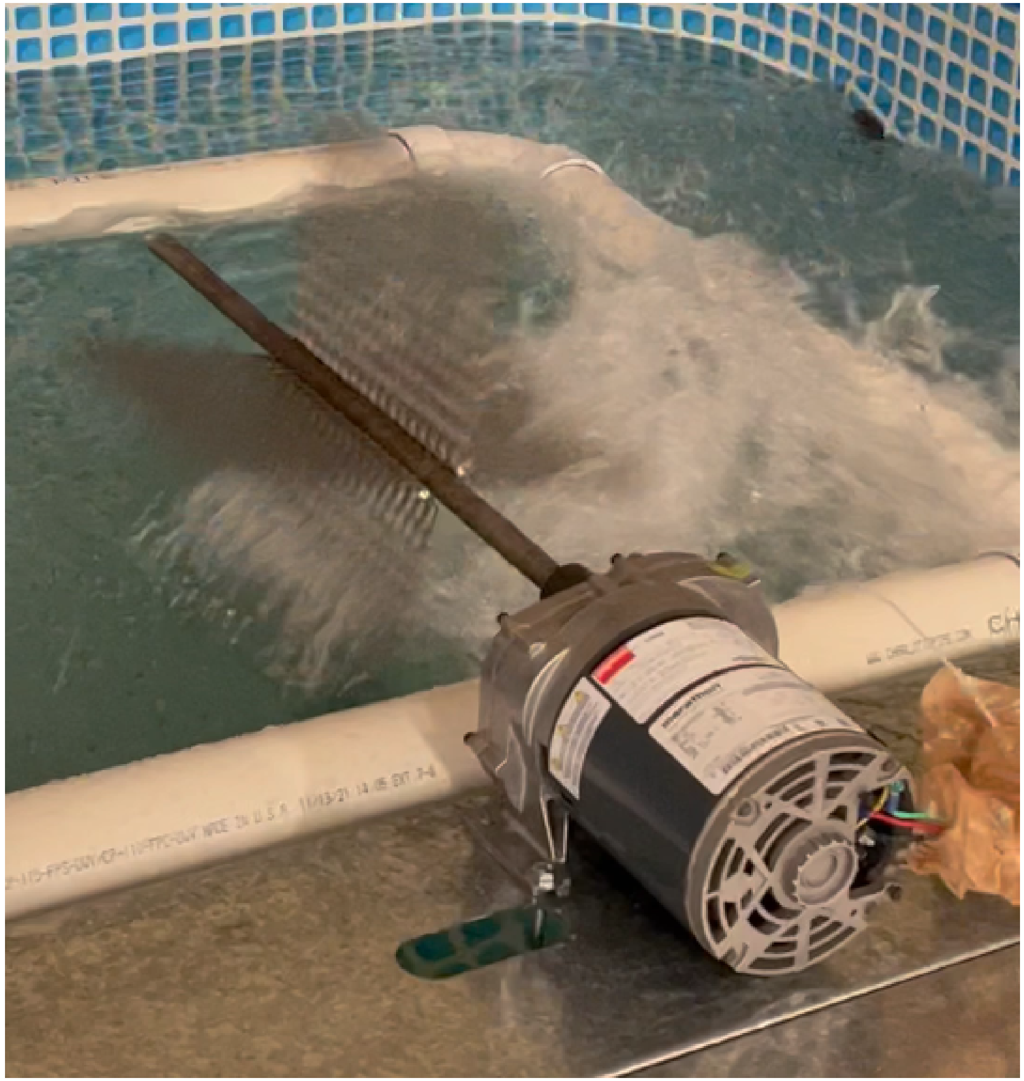
Collecting Data



Calculations

- $P_{solar} = \frac{P_{aerator} + \frac{C_{batt} * V_{batt}}{t_{sun}}}{\eta_{charge}} (1 + \kappa_c)$

- $C_{batt} = \frac{P_{aerator} * t_{no\ sun}}{V_{batt} * \eta_{inv} * (1 - SoC_{\min\ batt})}$

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Data Collected

Assumptions		
Inverter Conversion Efficiency	75%	
Charge Efficiency	90%	
Battery Nominal Voltage	12	
Operation Length w/ Sunlight	11.2	h
Operation Length w/o Sunlight	12.8	h
Battery min. SOC	30%	
Solar Panel Fudge Factor	15%	

Load		
Measured Aerator Power	200	W
Load Voltage AC (rms)	120	V
Load Current AC (rms)	1.667	A
Daily Aerator Power Consumption	4800	Wh

Power Specs		
Battery Capacity	406	Ah
Solar Panel Power	812	W

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Final Design

- Solar Panels
  - Quantity: 3
  - 275 W each
  - 825 W total; 812 W required

Final Design

- Charge Controller
  - Quantity: 1
  - ML 2440

Final Design

- Batteries
  - Quantity: 2
  - 12 Volt each
  - 250 Ah each
  - 500 Ah total; 406 Ah required

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Final Design

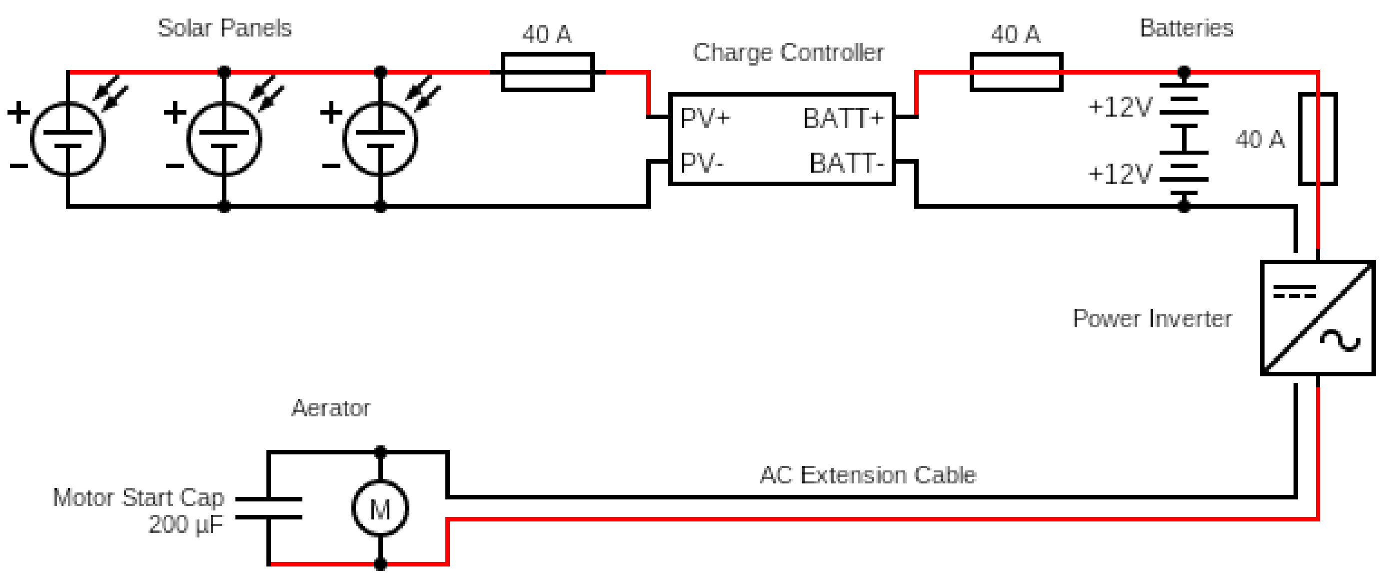
- Power Inverter
  - Quantity: 1
  - OP: Pure Sine Wave
  - 24 V
  - 1000 W

Final Design

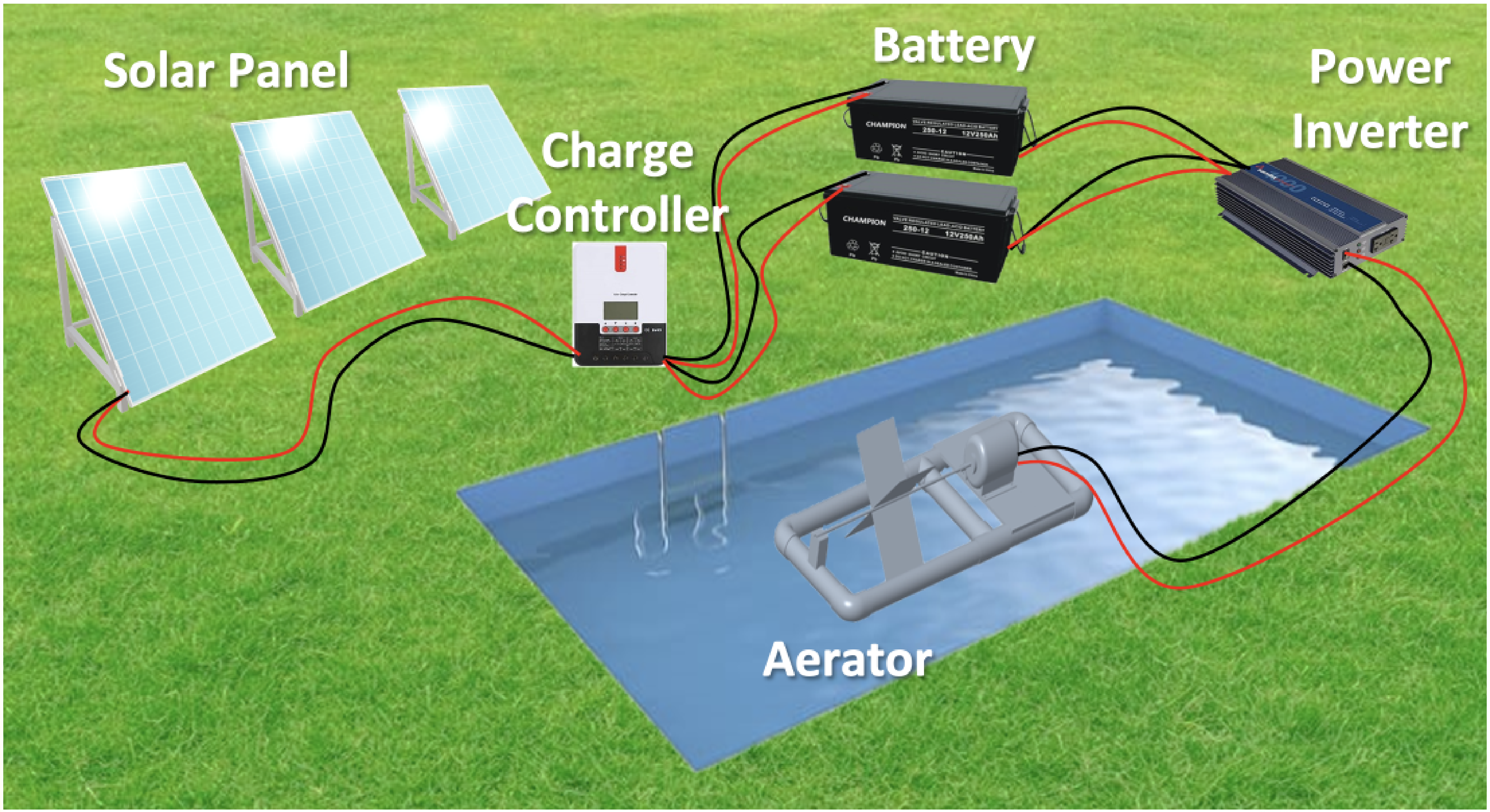
- AC Motor Configuration
  - **1LPN9 Dayton 1/4 hp 120 RPM 115V Dayton AC Parallel Shaft Gear Motor Dayton Model (5K942)**

Final Design

- Component Breakdown



Final Design



*Not to scale

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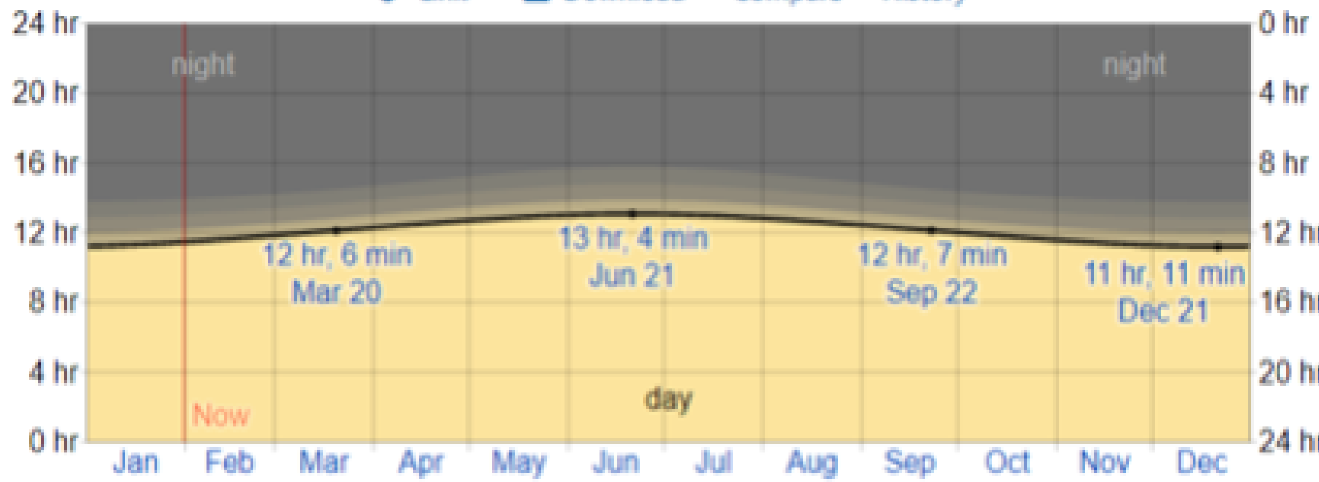
Operation Hours

- Hours of daylight throughout the year

Hours of Daylight and Twilight in Chisec

Link Download Compare History



The number of hours during which the Sun is visible (black line). From bottom (most yellow) to top (most gray), the color bands indicate: full daylight, twilight (civil, nautical, and astronomical), and full night.

Hours of	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daylight	11.3h	11.6h	12.1h	12.5h	12.9h	13.1h	13.0h	12.6h	12.2h	11.8h	11.4h	11.2h

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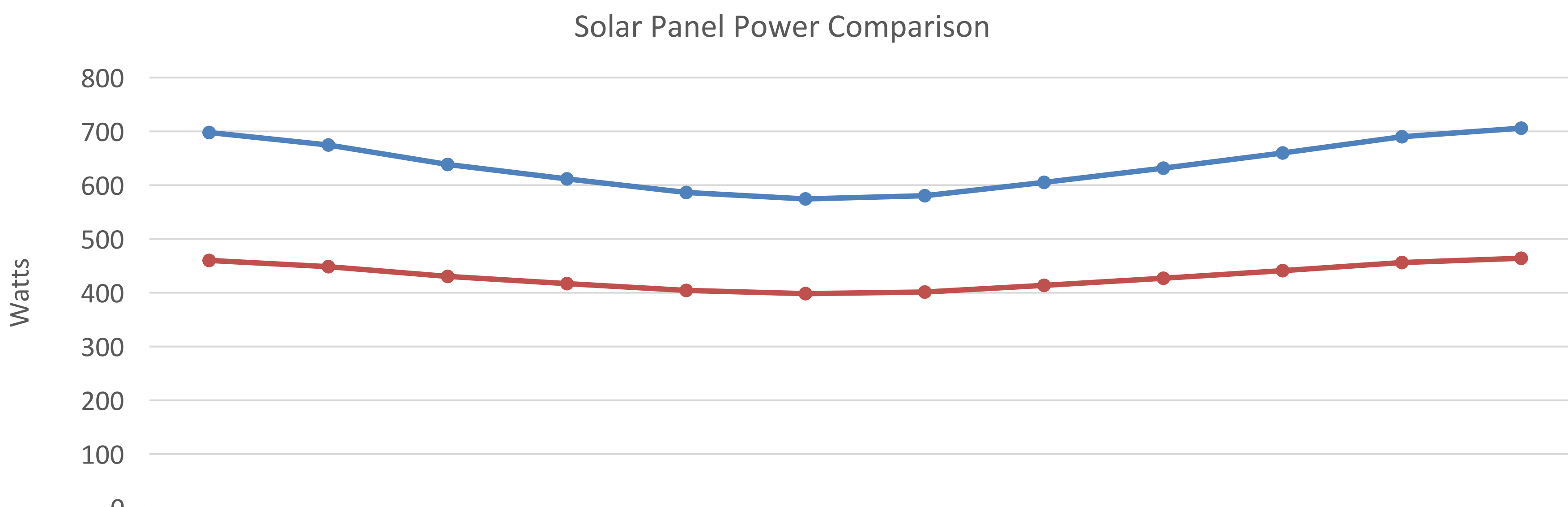
Operation Hours

Full Night vs. Half Night



	January	February	March	April	May	June	July	August	September	October	November	December
Full Night	698	675	639	612	586	574	580	605	632	660	690	706
Half Night	460	448	430	417	404	398	401	414	427	441	456	464

Full Night Half Night

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Operation Hours

Components	Full Night	Half Night
Rated Power Generation [W]	825	550
System Voltage [V]	24	12
Energy Storage Capacity [Ah]	500	250
Maximum Output Power [W]	960	480
Cost [USD]	$1,977.96	$1,170.30

Design Validation

Operation	Requirement	Testing Means	Measurement	Pass/Fail
Aeration	$0.5 \leq x \leq 0.7$ mg O_2/[L H_2O]	O_2 meter	To be completed	Pass*
SAE	SAE > 2 [kg×O_2/kWh]	O_2 meter/watt-meter	To be completed	Pass*
Energy Harvesting	Exceed aerator's power capacity	Watt-meter	825 W > 812 W	Pass
Energy Storage	Capacity is greater than required minimum	Watt-meter/battery specifications	500 Ah > 406 Ah	Pass

*Measurement will not be completed before the end of the project, but it is expected the operation will pass its requirements.

Design Validation

Operation	Requirement	Testing Means	Measurement	Pass/ Fail
Buoyancy	Aerator and paddle floats in pond	Inspection	PVC piping withstood downward force of aerator	Pass
Aerator Position	Aerator fixed in pond	Inspection	To be completed	Pass*
Weatherproof /Robust	Weatherproof and waterproof	Demonstration	Did not make progress in improving the design's weatherproofing	Fail
Accessibility	Components available in Guatemala	Geographical inspection	Solar energy components available in Guatemala	Pass

*Measurement will not be completed before the end of the project, but it is expected the operation will pass its requirements.

Design Validation

Operation	Requirement	Testing Means	Measurement	Pass/ Fail
Cost	Expenses < Profits	Cost analysis	$2,502.11 < $7,250.00	Pass
Durability	Component life cycle > one harvesting season	Inspection of component specifications	All components last longer than one harvesting season (34 weeks)	Pass
Safety	Electrical components protected from water shorting	Demonstration	Shielded high-power components with heat shrink and added fuses to the system	Pass

Challenges

- Pool
  - Punctured multiple times
  - Keeping clean and empty when not in use
- Available equipment in Guatemala
  - Finding what is available
- Trip
  - Scheduling conflicts

Conclusion

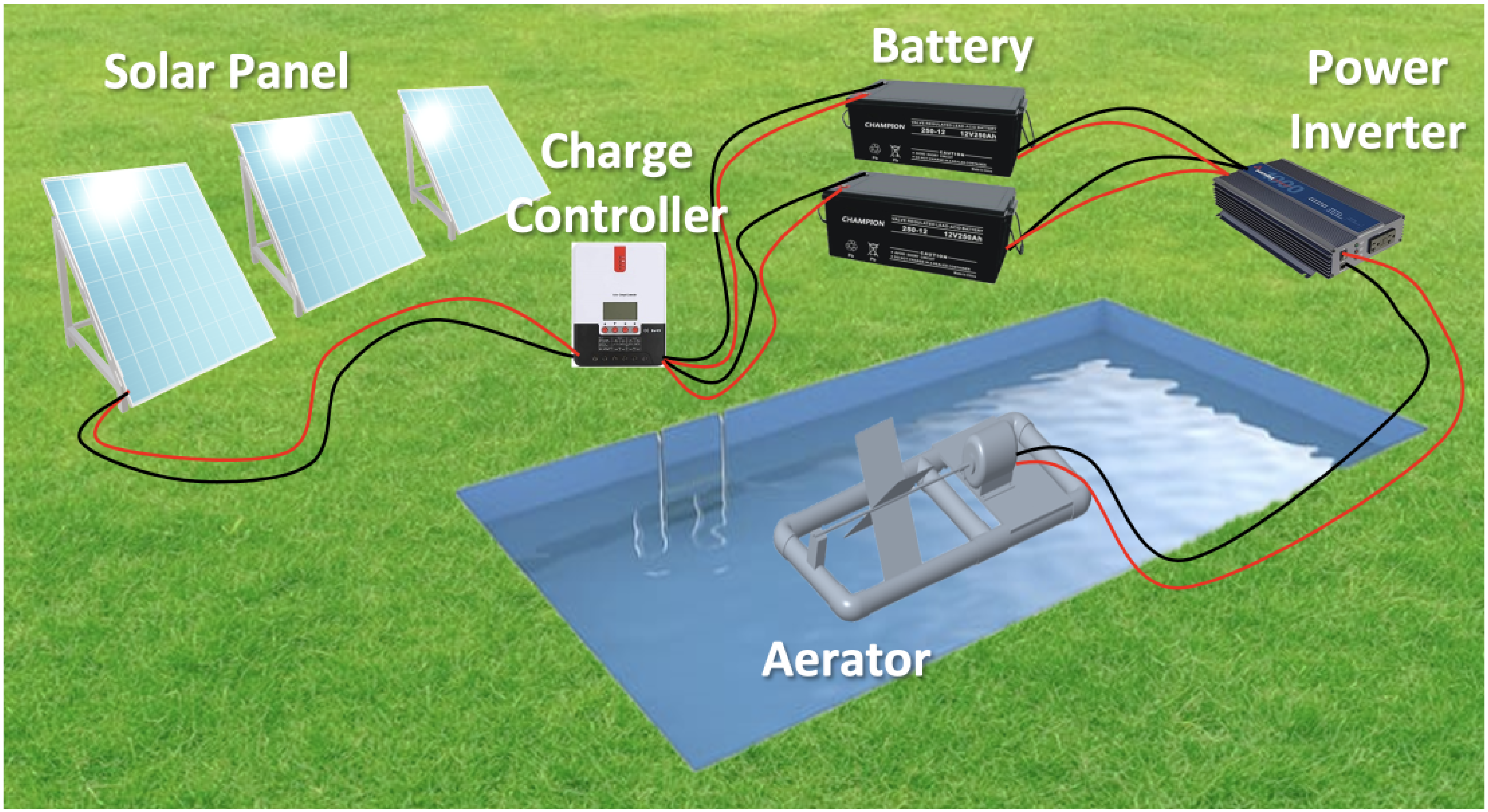
- Provision of Sustainable Energy
  - Aeration power not reliant on the grid
  - Possibility of alternate energy use
- Aeration for Tilapia
  - Protein supplement
  - Economic stimulus

Recommendations

- Rust-free paddles
  - Other materials: PVC, nylon, aluminum
  - Coat the steel in Rust-oleum or other protective layer
- Make a more robust design
  - Stronger coupling
  - Better bearing/support design
- Go to Guatemala to build the final system and find final developmental data

Q&A

- What questions do you have?



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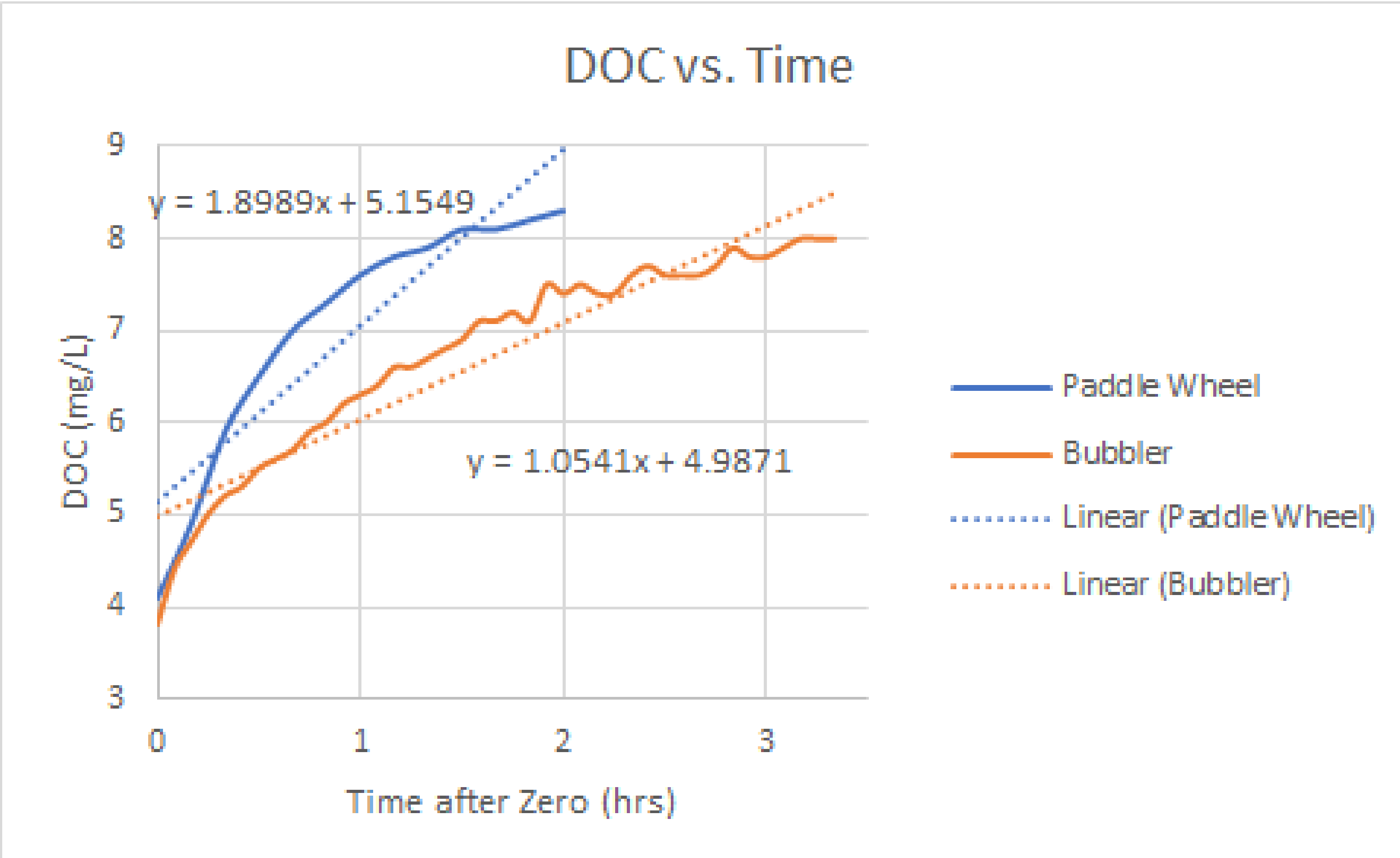
Aeration Operation Requirement



Minimum Theoretical Aeration work time:

12 Hours, 1 hour intervals

Cost Summary

Table 5.4 Expected Costs of Entire System				
Item	Description	Quantity	Cost (Per Unit)	Total Cost
AC Motor	¼ HP, 120 RPM	1	$380	$380.00
Capacitor	200µF, 125VAC	1	$12.70	$12.70
Terminal Rings	TERM RNG16-14G4-6ST 10PK	1	$3.59	$3.59
Bolt Fasteners	Hillman Fasteners	2	$0.45	$0.90
Power Cord	Cord Power 16/3 SJT 6’	1	$10.90	$10.90
PVC Corner Piece	3” 90 Degree PVC Elbow	4	$3.29	$13.16
PVC Middle Piece	3” Tee Schedule 40	2	$9.19	$18.38
PVC Primer	8oz Purple Primer/Cleaner	1	$4.89	$4.89
PVC Cement	8oz All Weather PVC Cement	1	$9.28	$9.28
3” PVC Piping	3” x 10’ Cell Core PVC Pipe	2	$26.82	$53.64
Driveshaft Coupling	Rigid Coupling, ¾” bore, 1 ½” OD, 2” length, 5/16-18 x 3/8 Set Screw	1	$14.67	$14.67
Solar Panel	275-Watt Rating	3	$171.65	$514.95
Battery	12 Volt – 250 Ah	2	$568	$1,136.00
AC/DC Inverter	24 Volt OP – 1000 Watt	1	$167	$167.00
Charge Controller	ML2440	1	$160	$160.00
			Total	$2,500.06