Project Proposal: Sustainable Low Cost Lighting

Design Team:

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Mission Statement:

To expand our market globally to rural areas of non-industrialized nations in order to facilitate their productivity by providing power and lighting with a commitment to environmental sustainability.

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Introduction

The purpose of this report is to come up with a detailed method to produce electrical power for lighting specifically for rural communities in non-industrialized nations. The design is overshadowed by many regional constraints that make this a very challenging but exciting project. There also has to be a strong commitment to environmental sustainability. Some of the logistical issues that must be considered are: **lighting needs, conditions of operation, operators, cost, service and repair plan, our competition and company image.** These issues are clarified further (below) and should be accounted for in the overall design proposal.

Regional Constraints:

- There is no nearby electricity sources
- There is no nearby phone
- There is no nearby potable water source
- There is a stream nearby about half of the village locations; however its water flow level is uneven. During rainy season, there is good current. During the rest of the year it only has enough flow to meet drinking water needs of the village. In about half the other cases the dwellings are distributed far from the steam.
- Living quarters are of the "hut" type (e.g., tree branches with a piece of plastic for a roof or sheet metals sides and top). None are wired for electricity. Many of the huts in the "village" are at distances of 1km from each other (since they are surrounded by either their crops or there are mountains in the way).
- Most of the villages are remote, and will take almost a day of driving, plus a 5-6hr walk in the mountainous terrain.
- Diesel fuel or gasoline in large portions (e.g. to run an electric generator, which is much too expensive anyway) is prohibitively expensive in most areas (partly due to problems with transporting it).
- During rainy season there is sometimes no sun during the day, or at most 2-3 hours of sun. During the dry season it is sunny almost every day and it gets quite hot. At night it gets cold in most locations since most of the villages are up in the mountains.
- In some locations, since many of the villages are up in the mountains, there is a relatively constant source of wind. However, that is above the forest canopy in many cases. And, the company has not done the very expensive survey that would be required to determine the wind characteristics in the many remote locations.
- A number of persons in the situations described above have taken to using kerosene lanterns for light at night. They purchase fual at the market once a month (cheap, but heavy to carry). These lanterns have been the cause of a number of fires. Also, since it is cold in the mountains at night, the huts are closed pretty tight, and the smoke from the lantern is causing significant health problems for them and their children who endure years of such contamination.

Lighting Needs: The lighting needs are prioritized in the following order:

1. Income: The parents find 1-2 hours of lighting at night useful for crafts making and other "cottage" industry type jobs they sometimes can get. The increase in their return from sales at the market (that is around 20km away) will provide clothing and better nutrition for their family, but no surplus funds.

2. Education: Children go to school in the morning, and then work in the fields in the afternoon until nightfall. It would be quite useful to have at least an hour of lighting at night for the children to read and study.

There is no hope that the government or anyone else will run electrical lines or a water supply to the village in the next 20-30 years. Some say that would "never happen."

Conditions of operation: Most of the huts leak some, and there is a 2-3 month rainy season. There are some periods of high humidity. Most of the huts have a dirt floor. Temperatures in the targeted areas range from 20 degrees F to 110 degrees F.

Operators: It must be possible for young children and adults to easily operate the device. It must be safe. We are quite concerned about safety and liabilities.

Cost: Nearly all persons could not sacrifice more than a few days to 1 week of income for the purchase. If it is more, they will just stick with the kerosene lanterns since they need to eat. Customer expectations are that the product would operate failure-free for at least two years of continuous operation. It must last at least 10-15 years in total. A significant challenge is that the costs of operating it must be as low as possible. It is not feasible to simply expect them to purchase batteries, not to mention concerns about disposal and pollution.

Service and Repair Plan: There must be a service and repair plan that is consistent with the above constraints. Discussed in this proposal are: warranty plan, return policy, qualifications for a valid return, service of these returns.

Competition: An extensive survey of our competition was conducted. We have provided a description of their products and their functionality, their cost, their warranty and support services, and their marketing penetration.

Design Specifications

Preliminary Design:

For our overall design we have two integrated ideas. First, for the rainy season where at most times, there is not enough sunlight to generate power, a hydro generator will be used. The hydro generator will be integrated into the locals' huts using a gutter system. The hydro generator will be used to recharge a battery. The electrical system will be discussed in a following section.

On some occasions when there will be no rain, the hydro generator can be detached from the spin wheel and a hand crank can be attached. Anyone can crank this to generate enough power to charge the battery. It will take about 5 – 10 minutes of cranking to fully charge the battery.

Figure 1: Gutter System

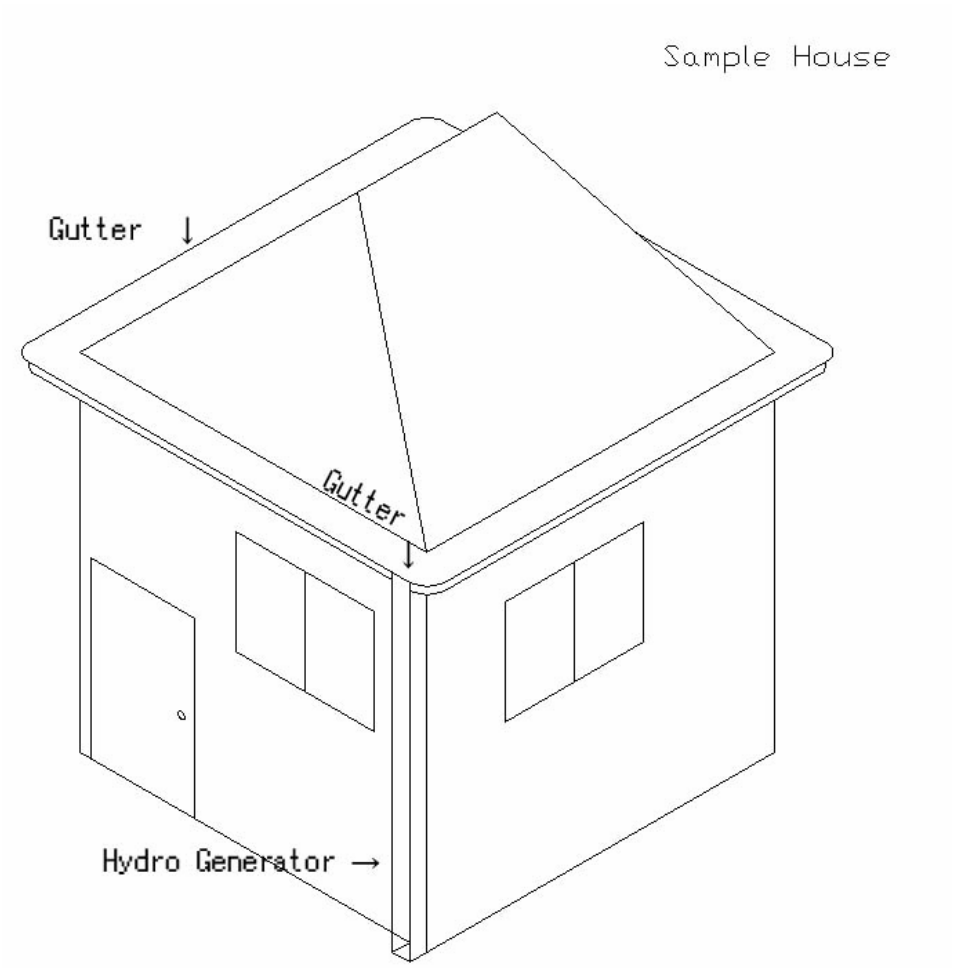
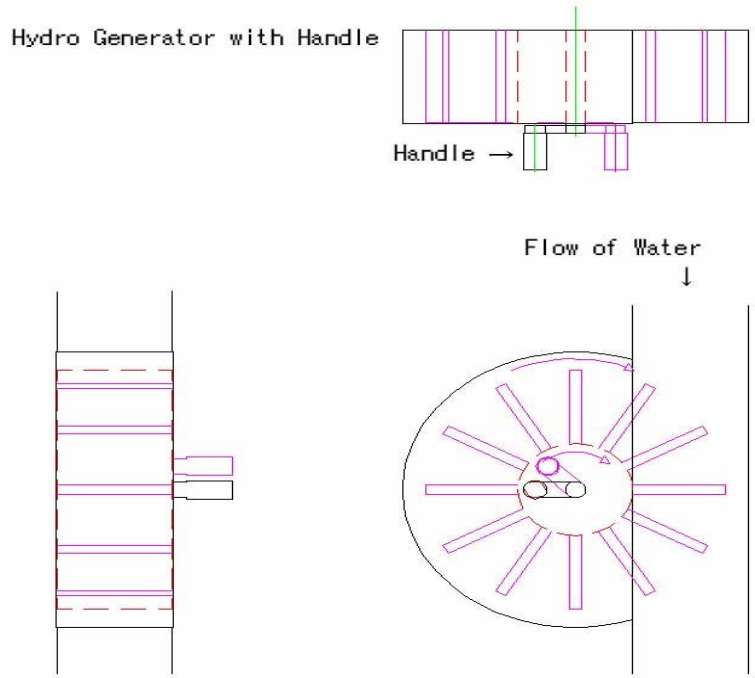


Figure 2: Hydro Generator System



Electrical System:

The system that we have designed is a basic circuit that will consist of three elements. A generator, a rechargeable battery, and an LED light source. Our design can be seen below in Figure 3.

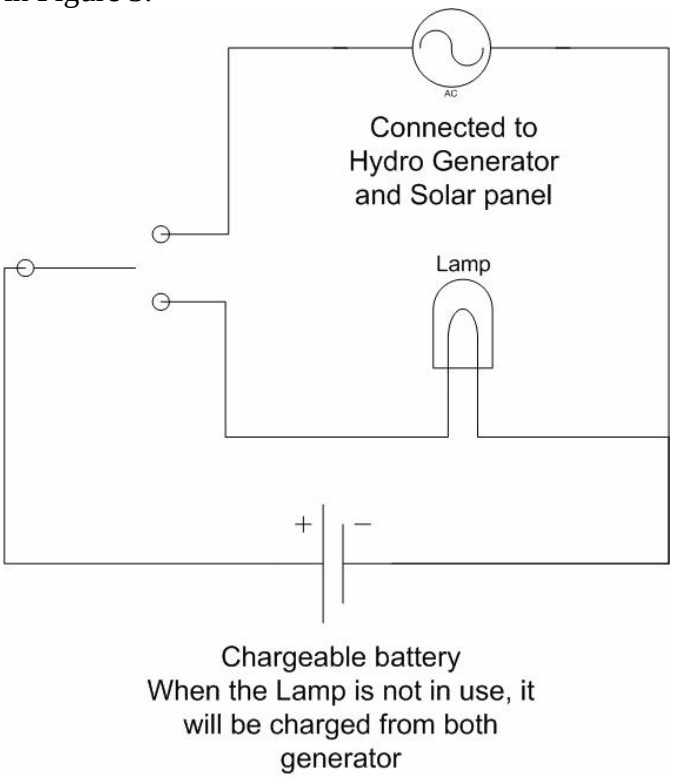


Figure 3: Electrical System (left)

It can be seen from Figure 3 that when the switch is in the present position, neither the lamp, nor the generator will be connected. When the switch is flipped up, the lamp will be ON and when the switch is flipped down, the generator will be in a closed loop with the lamp, producing light directly from the generator.

Marketing & Logistics

Home & Power Integration

The logistics of the proposed design follow from either a stationary mount via the hydro paddles or a semi portable unit via the hand-crank, battery and LED bulb. The unit comprised of all these parts is not presently being offered as a “portable” unit, however all the components can be moved individually to allow freedom to customers.

The main idea behind integrating our product to existing huts is to utilize the metal roofs for rainfall, filtering the water flow into a cheap purchasable gutter system. The gutter system includes a paddle wheel which allows the “hand-crank” generator to become a temporary hydro generator. If the rain lasts for over an hour then there would be enough energy to charge the battery to provide approximately 24 hours of light.

Service and Repair Plan

The gutter system is not necessary to purchase and still obtain a feasible light solution from our product line. It suffers depreciation mostly due to environmental factors such as excessive water flow, clogging due to fallen leaves etc. But because the gutter system is not a complex component of our package, and most depreciation will only occur during the rainy season, it is easily repairable by the local townspeople. It requires no technical expertise, and the most common problem would be clogging which can easily be fixed.

The hand-cranked generator is purchasable without the gutter-system for a cheaper price. This would allow for that clientele without metal roofs to obtain the same light though they would be required to crank their own power. This comes with a full 10 year warranty.

The products offered are easy in their localized repair such that if a component fails it will most likely need to be replaced (i.e. battery, LED bulb, ext.) In case of a component failure it would be most convenient to our clients to have a central location to make an exchange. A general store or local market that supplies the village would be the best location. In this way the company could incorporate the local market in the sales of its products. We shall offer a 4 year warranty on our rechargeable batteries, and a 10 year warranty on our LED light bulb, and our generator.

Cost Analysis

Table 1: Cost Analysis Spreadsheet

	Cheap Hydro Generator	$100.00	12v @ 100mA max	
	Dynamo Generator with gutter addition	$12.00	6.3V @ 300 mA	
Solar Power	Silicon PowerFilm	$40.00	15.2V 50mA	10 year warrenty
	EpoxLite Solar Panel	$15.90	6V @ 300mA	10 year warrenty
	Matrix SolarPanel	$379.00	17 V @ 5.4 A	25 Year warrenty
Batteries	Trojan 12v Deep Cycle	$70.00	200 min @ 36amps	2.5 hours of light
	Tysonic 12V 1.2A/h	$8.59	1.2 A/h max	1 hour of light
Chosen Battery	Tysonic 12V 12A/h	$23.00	12 A/h max	6 hours of light
Charger	interface from solar to battery	$8.00	included in all	
Light Source				
LED	1157 12 LED 12V about 1/2 watts	$6.99	included in all	
Bulbs	@ **LOWE'S**			
	60 W 4Pack	$0.78	***too much power***	
	7 W 1 Bulb	$4.98	***still too much power***	

Competetors & Resourses

http://www.siliconsolar.com/
www.discountpv.com/lighting
www.wholesalesolar.com
www.eurorex.com/ugtoges/intro.htm
www.otherpower.com/wardsolar.html
www.ampair.com/homepages/index.php
www.microhydropower.com/
www.otherpower.com/scotthydro1.html

Package	Cost
Solar 1	$77.99
Solar 2	$69.79
Hydro 1	$137.99
Hydro 2	$49.99

Cost Analysis:

The cost analysis focused on a design idea that was cheap, easy to manufacture, and easy to repair. Multiple ideas were put forth and researched as in solar, stream hydro-generators, roof hydro-generators, hand-crank dynamo generators and others. The solar power seemed to be just out of the price range and was very difficult to repair. A combination of hydro and hand-crank generators was fallen upon because all the requirements seem to be met.

With the power “supply’ chosen, the team sought a cheap way to store the energy use. The sealed lead acid battery was chosen for cost purposes and long lasting power supply. These batteries are also very simple to recharge and require little in the way of safety circuitry for charging; unlike other battery choices.

The LED bulbs were clearly a superior choice to any other current “bulb” technology. What minimal losses there are in luminosity are easily returned upon with power saved. The LED bulbs chosen were costly but they are insured by the manufacturing company for 10 years and price negations can be made for bulk order. The present quotes are for low quantity purchases.

The final design incorporating the hand/hydro dynamo generator, battery, and LED bulb comes to a total cost of $49.99. This product produces 24 hours of light when the battery is fully charged. It is possible to offer a cheaper model of the product via a cheaper battery that allows 3.5 hours of light when fully charged. Though no exact testing has been done, it is estimated to take about an hour of hand-cranking to fully charge the higher end battery.

These quotes are all in low quantity purchases. For ease of purchase and quick delivery time most of the products are from American vendors. For further cost reduction to boost profit and clientele from lowered prices, it would be easy to get better quotes by make large “bulk” purchases from the manufacture. If cost reduction can’t be met through improved business relations then outsourcing the products to other countries and suppliers may be considered.

The countries in question which would be interested in the product are also a source of cheap labor. There may be cost benefits and reduced shipping costs if the product was manufactured in the specific country. This would allow ease in training associates involved in repair and upkeep of the product. If the company acted ethically in the country in question, this would increase the respect of the product in the eyes of potential clients acting as a source of advertising through local employees.

What We are Doing to Help

The design we chose stands tall with our commitment to environmental sustainability. Our goal to provide power to rural non-industrialized societies without greatly disrupting their working and living environment was met. In this case, it is a much better alternative to build a simple device rather than call for a drastic change to the environment such as building a dam. These people rely on their environment to live, and any drastic changes can be very detrimental to their society. We were able to build a simple system that exploited the kinetic energy of the rain. Our gutter system is cheap and easy to install. It is also an improvement on their civil environment. By directing the water it serves as a basic gutter, and also turns that directed water into kinetic energy. The batteries that we use can also be recycled at our local plant. This way they will be able to dispose of the batteries in a proper manner without harming the environment.

Our technology transfer is very good. Our product proves environmentally sustainable. To produce energy we simply use a proven piece of technology such as the generator. We were able to improve their living conditions by installing a gutter system. By doing that we are also able to create energy with the rain, and propel a spin wheel which is made out of environmentally friendly materials. This spin wheel will run the generator which will then produce electricity for a LED. The LED’s last a very long time. We are confident it will last longer than 10 years. This proves to produce little waste.

Appendix A: Competitor information sheet:

http://www.siliconsolar.com/shop/product.php?productid=74&cat=0&page=5

Dual Solar Spot Light Set

This unique set of lights offers two times the illuminating power of our standard solar spot light. This lighting system is designed to run from one central power center, branching off into two separate lights. Great for using illuminate an area of shrubs, small signs, and outdoor landscape decor. Each light is made with three 10,000 MCD white LEDs powered by a 6v solar panel.

Our most powerful solar floodlight includes two adjustable lamps, each containing three white LEDs, to provide improved light output. Each lamp features a ground stake and surface-mounting bracket for a variety of installations. Each lamp is connected to a remote solar collection panel via 20 feet of weatherproof cable. The solar panel swivels in any direction for optimal solar energy collection.

This state-of-the-art solar accent light provides more power than leading solar lights sold across the world. Engineered after many requests for a long lasting, high output solar light, the SiliconLight Plus is equipped with nine 13,000MCD bulbs. This unit is not like others advertised, which contain only one LED and produce an inadequate, dim light; this unit utilizes three LEDs to stay lit up to 15 hours and operates on a low voltage system, allowing for a brighter and longer lasting light.

Each light automatically turns on at dusk and off at dawn and is weatherproof. Manufactured by Intermatic, integrated with Silicon Solar components for increased performance.

SKU:	06-1010
Weight	4.00 lbs
Price:	$49.95

Warranty: 4 year warranty
Materials: ABS Plastic , High Density Single Crystalline Solar Panel
Dimensions: Lamp Size: (Main Body): 4" high x 5" wide, with ground stakes and top, 9.5" tall with power center (5.5" x 6.5") Include ground stakes & deck anchors.
Light Output: 36 watts, 15hours
Lighting Area: Accent Spot Light 5-7 feet (3 separate areas)

http://www.eurorex.com/ugtoges/light.htm

Off-Grid Lighting Technologies

DC Electric Lighting Systems

Electric lighting systems are superior to fuel-based lighting systems because of convenience, cost, safety and overall quality of light output. Small, 12 or 24V DC lighting systems are appropriate for systems of between 1 and 20 lights. They can cost-effectively be powered by lead-acid or nicad batteries recharged by PV, wind, and, in some cases, generator sets or central recharging stations. It is often economical to have a number of dispersed lighting systems rather than a central interconnected system. In general, DC lighting systems should use fluorescent-type light fixtures, as they are much more efficient than incandescent or halogen alternatives. Low-power incandescent lights (3-10 W) can be used for ambient lighting needs. Halogen lamps with reflectors are ideal task lights. Note that PV lighting systems must be properly sized, using the daily energy requirement. Wind turbines can also be used to power lighting systems.

Table 3: PV Lighting Kit Prices

Component	**Typ. Market Price [US$]**
PV module 50 Wp (4.5$/Wp)	250-320
Battery 100 Ah (lead-acid)	65-100
Charge controller	50-100
Cables, switches & mounting struct.	40 - 100
Fluorescent lamps 11 W x 4	100 -140
Commissioning & overheads	40 -100
System costs (not including taxes)	**$ 580 - 950**

http://www.wholesalesolar.com/gridtie.html

Solar Grid-intertie Systems

	Sun Hrs per Day	Sun Hrs per Day	Sun Hrs per Day	Sun Hrs per Day	Sun Hrs per Day	Sun Hrs per Day
Find your Solar Zone from the map.	**2.5**	**3**	**3.5**	**4**	**5**	**6**
Gridtie System Number	**Kilowatt Hours per: Day / Month**	**Kilowatt Hours per: Day / Month**	**Kilowatt Hours per: Day / Month**	**Kilowatt Hours per: Day / Month**	**Kilowatt Hours per: Day / Month**	**Kilowatt Hours per: Day / Month**
GT-1.8	4 / 120	4.7 / 141	5.5 / 165	6.3 /189	7.8 / 234	9.5 / 285
GT-2.5	5.9 / 177	7.1 / 213	8.3/ 249	9.5 /285	11.8 / 354	14.1 / 425
GT-5.0	11.8 / 354	14.2 / 426	16.6 / 498	19 / 570	23.6 / 708	28.2 / 850

http://www.ampair.com/catalog/product_info.php?cPath=67&products_id=201&osCsid=9e68a67f1cf1ef1ad5792dd306237126

B. 12 Volt/ 11 Watt Fluorescent Lamp £15.04
[11E E27/BC]

!2 volt/ 11 watt, compact, 'energy saving' fluorescent lamp fits bayonet base (BC). This enables standard lampholder fittings to be used for wiring DC light circuits. Cool white output equivalent to a 60 watt filament lamp. Other ratings and large screw caps (ES) are available. Size 160mm high x 55mm diameter.

For more information, please visit this products webpage. Click to enlarge Click to enlarge

This product was added to our catalog on Thursday 22 July, 2004.

http://www.microhydropower.com/

"Innovative Micro-Hydro Systems Since 1980"

The Stream Engine employs a brushless, permanent magnet alternator which is adjustable, enabling the user to match turbine output to the electrical load. It has higher efficiency than previous alternators, and is capable of outputs over 1 kilowatt (kW). **All Stream Engines are equipped with a rugged bronze turgo wheel**, universal nozzles (adaptable to sizing from 3 mm (1/8 inch) to 25 mm (1 inch), and a digital multimeter which is used to measure output current. The entire system is made of non-corrosive alloys for long life and durability. This machine can produce power from heads as low as 2 metres (6 feet) to over 100 metres (300 feet).

Bronze Turgo Wheel

Stream Engine (Bottom View)

Stream Engine (SE)	
2 Nozzle SE Standard	$1895
4 Nozzle SE Standard	$2045
2 Nozzle SE Bronze	$2395
4 Nozzle SE Bronze	$2545
High Voltage Option	$200 extra
High Current Option	$100 extra
Water Baby	
Baby Generator, 1 Nozzle (12/24 volt)	$1395
Extra Nozzles (installed)	$120 each
High Voltage (48/120 volt)	$100 extra

Appendix B: How to build a Hydro Generator:

http://www.otherpower.com/scotthydro2.html

Homebrew Hydro Electric

Hydro Electric experiment with direct drive PM Alternator

Pictured above is our neighbor Scott's Dam. He's got a 4" diameter PVC pipe out of it, running down the creek about 15'. The total head here is about 3'. Our goal is to build a small hydro electric plant. In the past he had a machine he'd built from a squirrel cage blower, with a belt, to a PM DC motor. It produced about 1 amp, give or take a bit and he ran it year round for 2 years. It provided most of his power during that time, more than enough for a couple lights and a radio. Scott came up this spring and helped build a wind turbine for his place, Click Here to see that! We figured, if we built a similar alternator for the hydro plant, that we did for his wind turbine, and perhaps improved the wheel a bit, we could capture a bit more power from this dam!

We started with scraps of sheet metal and angle iron. The disks for the runner were made from the base of a dead Onan Generator. The alternator was built from two 11" diameter brake rotors (we think they are off a Dodge but not sure), and the spindle/wheel hub also... probably from a Dodge, but were not sure because it was salvaged off other homemade equipment.

The Vanes in the runner are made from quartered 4" diameter steel conduit.

The sides of the runner are 12" diameter. We made a template which helped lay out the holes to fit the runner to the wheel hub (5 lugs) and layout the exact position, and angle of the vanes. The idea behind this was to make something along the lines of a "Banki" turbine, which looks a lot like a squirrel cage blower. In the Banki turbine, if one was looking at the side, the water should enter below the top (perhaps around 10 O'clock), pass through the middle of the wheel, and exit near the bottom (around 5 O'clock), so the water actually hits the vanes twice. We looked at lots of pictures and took our best guess regarding the width, and angle of the vanes. Pictured above were punching all the locations for the edges of the vanes, and the holes which will mount the runner to the alternator. The runner has 16 vanes.

The template is glued to one of the disks which make up the sides of the runner, and we have both disks clamped together. Pictured above we're drilling small holes which will help us know exactly where to postion the vanes.

We put 10" between the two sides of the runner using allthread, and squared it up as best we could before installing the vanes. You can see some of the holes we drilled to help with postioning the vanes.

Here the runner is getting welded up. It's important to note... the vanes are made of galvanized steel conduit. We had to grind all the galvanization (Zinc) off the edges before welding this... welding galvanized metal produces toxic gas, so we try to be careful about this.

Pictured above the runner is pretty well tacked together. We'll add a bit more welding later. It's not been shown yet (but later will be), one side of the runner (the side opposite the alternator) has a 4" diameter hole in in the middle, so that we could more easily bolt

it to the alternator, and get our hands in there to remove sticks and such that might get stuck in it.

The nozzel will be the same width (10") as the runner, and it's about 1" wide where the water exits. This gives about the same area at the end of the nozzel as the 4" pipe that feeds it... slightly less. Pictured above we're bending the sheet metal which makes it up.

Pictured above it's starting to take shape. We've mounted the runner to the hub, and basicly assembled everyting except for the alternator. Everything on this is adjustable. We can move the nozzel forward, back, up, and down. The runner (and the alternator) can be moved back, and fourth.

We made the connections on the stator and it's ready for casting. Each coil has 125 windings of #17 wire. Each phase has 3 coils in series, and we'll be bringing out 6 leads, so that we can choose between the Star, or Delta configuration.

Pictured above is how the stator looked after casting. It's 14" diameter, and 1/2" thick... it came out nicely.

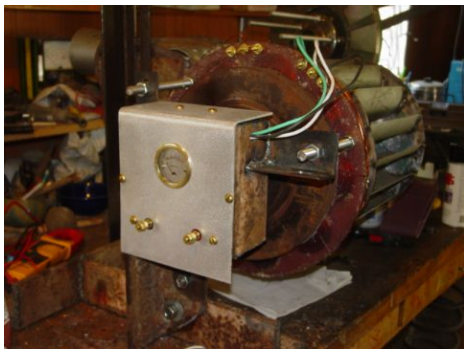
I made a template from plywood to make positioning the magnets on the brake rotors easy. Pictured above is the template, and one brake rotor.

Pictured above we have the magnets positioned, and the template in place. The magnets are 1" X 2" X 1/2" thick, there are 12 on each rotor. This part of the machine is almost identical to the alternator in Hugh Piggott's Axial Flux Wind Turbine plans. The magnets are available HERE.

We used Polyester fiberglass resin for casting both the stator, and the magnet rotors. Here the resin is setting up, once hard the magnet rotors will be finished.

Pictured above the machine is about finished up, the alternator is assembled.

Here is a picture of the other side. There are two bridge rectifiers behind the Aluminum cover to rectify the 3 phase AC in Direct Current. The meter has a 6 amp scale. At this point, with the airgap between the magnet rotors taken up as tightly as possible, it produces 12.5 Volts DC at 38 rpm. The back magnet rotor has 3 jacking screws so that we can adjust the airgap, and allow the alternator to run faster if we need to, in hopes of matching the speed of the alternator to the optimal speed of the runner. Lots of adjustments on this machine!

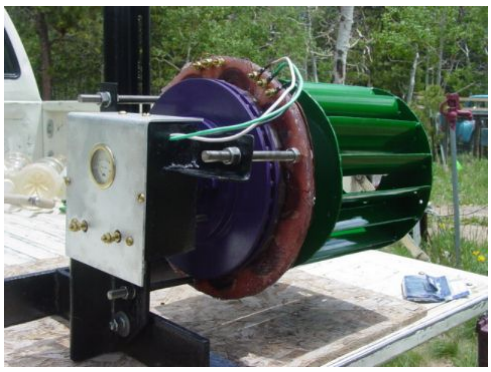


So that's where we left off on Page 1 of this project. So far we've got about 3 days into it all! It's lot of fun doing this sort of thing.. even if it doesn't work!

It's amazing how we can fit a hydro project, a big wind turbine project, lots of tools, and 17 folks with instruments including a standup bass in half of my 10 X 50 trailer!

Back to work. We spent about 2 hours grinding rust off it, sprayed primer and paint over it. Probably not necessary, but it makes it look nice, which is especially important if it doesn't work!

Here it is all painted up! We'd intended to put a



shroud over the alternator that would rotate with it, to keep water out of the bearing and off the electric components. We never found the right piece and ran out of patience with that, but we will add that later if it works well enough to warrent the effort.

Another shot of it assembled. We've not put the nozzel on it yet, it's in the back of the truck.

Pictured above you can see where we plan to put it. The 4" pipe comes from the bottom of the dam, again.. about 3' of head. Its a thoughtful arrangement. We're only taking a small portion of the water from the creek here. Up above the dam there is a bit of an island which splits the creek. Some of it feeds the dam, the rest of it flows round the side so as not to interrupt the creek.. fish can still go back and fourth, and if the creek is high, it won't have much affect on things.

This is Scott's old machine, which ran for 2 years even through the winter. Again, it was good for about 1 amp (12 watts) or so. It's a squirrel cage blower, belted up to an Ametek computer tape drive motor. To get an amp from it, the belt tension was very critical and required frequent adjustment. It was a good machine though! Hopefully what were doing here will be an improvement...

Here we've got the machine at the site, and are making adjustments. Again, just about everything is adjustable here! In the end, we got best results by feeding the water in at about 10 O'clock on the wheel, most of the water seems to exit at about 5 O'clock.

Here it is running along making about 2 amps (1.9 amps to be precise). We were hoping for at least 2.. but after lots of adjustments we simply couldn't beat 1.9! It's tricky to adjust! Every change we made to the alternator changed the best nozzel position. We could adust the airgap on the alternator, and we could change the wiring from Star to Delta. I definitley noticed higher efficiency in Star... it always produced slightly more power at the same rpm in Star with a wide airgap than it did in Delta with a narrower airgap. (the airgap is the distance between the magnet rotors and widening it reduces the flux through the coils allowing it to run faster) We left it in Star, with an airgap of about 1.25" (pretty wide!). So, it could be made at lower cost with smaller magnets, and a narrower airgap, or... it could be slightly more efficient with the same magnets, a narrower airgap, and coils made up of fewer windings and thicker wire. We may make this change at some point. As it is, it runs without a load at about 160 rpm, and loaded at about 110, producing 1.9 amps @ 12 volts.

Well, it was lots of fun and it seems to work reasonably well. We need a shroud over the alternator to keep the water off and a screen over the intake. One problem that I never thought of... the creek is full of magnetite sand! Even after a couple hours I could see a little building up on the magnets. It might payoff to have a screen, and lots of magnets at the intake to collect some of that before it gets to the wheel. A shroud over the alternator would also serve well to keep almost all the water out.