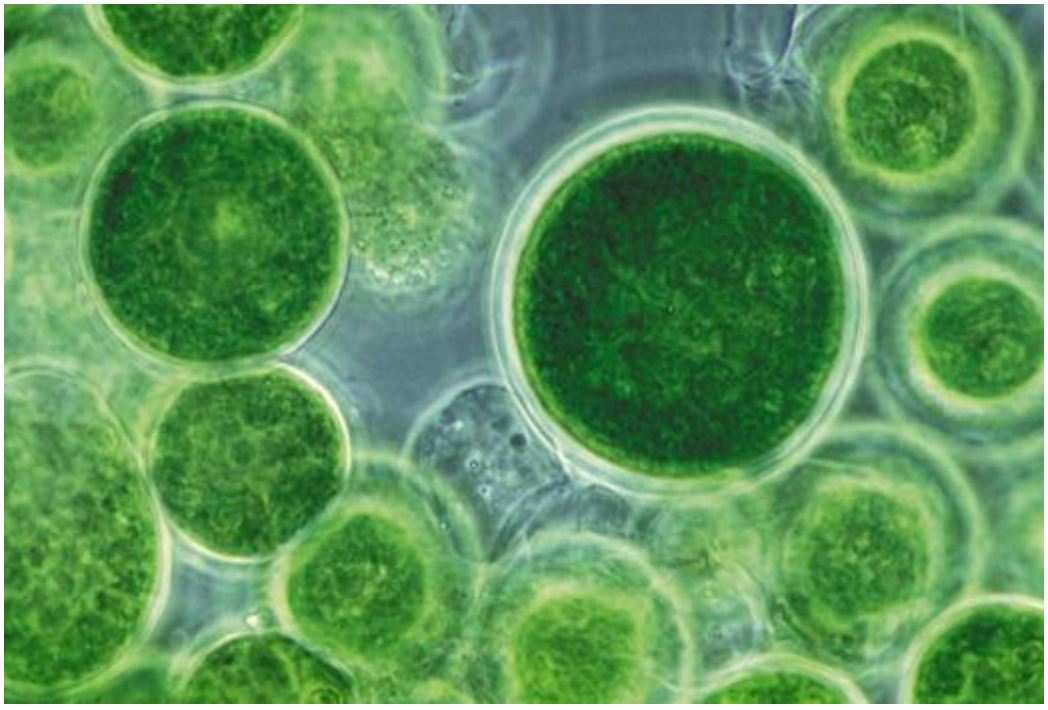
ENERGY NEPAL

WILD HARVEST OF HIMALAYAN RIVER ALGAE FOR BIODIESEL PRODUCTION

A Survey of Natural River Systems throughout Nepal

River Systems and Dry Season Riverbed Cultivation for Large Scale Production of Algal Oil for Transportation Fuels and Rural Development



Submitted to Bishnu Adhikari
Choice Humanitarian Nepal

By David DuByne, January 2011

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1.1 Executive Summary

This study will show the possibilities of collecting wild harvested Himalayan river algae on a scale large enough to produce algae biodiesel to supplement the national fuel delivery chain. Nepal contains the second largest water drainage reserves in the world after Brazil, and has approximately 45,000 kilometers of rivers and 200,00km of streams, meaning that the possibility of positive economic impact to every segment of society is achievable. I have spent the months of November and December 2010 walking rivers of varying sizes, altitudes and terrain talking an initial survey of the amount of wild algae in each type of river and possible harvest yield.

Based on my own observations I have seen algae in 70% of the rivers that I checked at different concentrations. In areas such as Hetouda and Damauli where the river becomes flat and wide and multiple streams wind through the dry river bed, those places have a concentration of a metric ton or more per kilometer. Areas at a higher elevation and steeper inclines the rate drops to 100-200 kilograms per kilometer. (Average yield: wet weight hand squeezed 1 kg = dry weight 380gm).

I have observed algae growing in; rice fields, small streams, small rivers, large rivers, concrete water holding ponds in Kiritipur and around Kathmandu, even in swimming pools. It really is everywhere and anywhere there is water which demonstrates the economic benefit of algae biodiesel production can be everywhere and every district as well.

In addition to wild harvesting by hand the river beds could be cultivated by moving stones to divert water and create long finger pools which become algae beds. It's a basic recreation of the same conditions that allow more algae to grow in conditions it already thrives in. Helping nature by creating the perfect environment for more algae to grow naturally is known as alga-culture and can be taught across the country so in the following years algae can be grown and harvested. Education programs must also be included with this project.

As income is generated through this program jobs can be created and excess proceeds from biodiesel sales can be put back into the local community in the form of roads, schools, hospitals, town planning, energy efficiency increases in the community, trash collection, reforestation etc.

One segment of society that will benefit is the impoverished rural farmer which can harvest algae with no start-up costs such as seeds and fertilizer and use the pressed algae biodiesel in their tractors at reduced cost. This money saved from lower fuel prices and monthly income from algae collection can increase their disposable income and purchasing power.

1.2 Background of Algae Biodiesel

Algae fuel is an alternative to fossil fuel and has nearly the same chemical properties as crude oil. Several companies and government agencies worldwide are exploring ways to reduce capital and operating costs and make algae fuel production commercially viable. [1] High import prices of oil purchased from India and making use of riverbeds not suitable for agriculture put algae out front as an attractive alternative fuel source. Algae has been researched as an alternative fuel since the early 1970's, but when crude oil prices fell to 8$ a barrel in the early 1980's research was put on hold.

Comparison of *Biodiesel* from *Microalgal* Oil and Diesel Fuel

Properties	**Biodiesel from Microalgal Oil**	**Diesel Fuel**
Density Kg l^{-1}	0.864	0.838
Viscosity Pa s	5.2×10^{-4} (40 °C)	$1.9 - 4.1 \times10^{-4}$ (40 °C)
Flash point °C	65-115*	75
Solidifying point °C	-12	-50 - 10
Cold filter plugging point °C	-11	-3.0 (- 6.7 max)
Acid value mg KOH g^{-1}	0.374	0.5 max
Heating value MJ kg^{-1}	41	40 - 45
HC ratio	1.18	1.18

*: Based on *data* from multiple sources
Source: Department of Biological Sciences and Biotechnology, Tsinghua University, Beijing , China (2004)

The United States Department of Energy (DOE) estimates that if algae fuel replaced all the petroleum fuel in the United States, it would require 15,000 square miles/39,000 square kilometers of grow out area which is only 0.42% of the U.S. Since Nepal's energy needs are considerably less that the U.S. it is feasible that there is enough wild algae in the river systems of this country to not only replace imports from India, but leave access to export to India. That is if all of Nepal's algae resources are utilized. [2] Nepal's energy needs are far less than the USA per day. *Nepal Oil – consumption 18,000 Barrels per day (bbl/day) (2009 est.) Nepal Oil – imports 16,920 bbl/day (2007 est.) [3]*

Factors

Dry mass factor is the percentage of dry biomass in relation to the fresh biomass; e.g. if the dry mass factor is 5%, one would need 20 kg of wet algae to get 1 kg of dry algae cells. [4]

Lipid content is the percentage of oil in relation to the dry biomass needed to get it, i.e. if the algae lipid content is 40%, 1 kg of dry algae would yield 400 grams of oil. [5]

Specific Research

Only few studies on the economic viability of algae production are publicly available, and must often rely on the little data (often only engineering estimates) available in the public domain. This gives us a distinct advantage in that we can publish data on wild harvest from natural water sources which will attract consultants, advisors and professionals to visit Nepal and help on this project. We need to demonstrate that with very low labor costs, capital cost, and operational costs wild harvested algae can be cost-competitive with conventional fuels and actually come in cheaper per barrel produced. There is currently no research or peer reviewed studies that I could find on wild harvest projects, we would be the first to publish this type of information.

Being the first to publish this type of large scale study will focus attention on Nepal as a new energy capital for fuels and grant money should flow from outside governments and companies and renewable energy labs.

2.1 Goals of Profitability and Revenue Generation

I firmly believe that the initial seed money to start this project will only be needed once, after that a sustainable revenue stream can be created which will fund the algae biodiesel project from that point forward. *This is the goal, start a project that generates money from itself and becomes self sustaining with a high profit margin. These profits can then be used for community based natural resource management, poverty reduction, water resource management, livelihood improvement in impoverished rural areas by providing skills training for locals in renewable energy.*

Looking at Nepal's river resources there are more than six thousand rivers and among these one thousand rivers are more than 11km long. More than 100 rivers are longer than 160 km and the total length of all rivers in Nepal is approximately 45,000 km. Expanding on the figures, lets take into consideration Nepal's three categories of rivers; The largest systems from east to west Koshi, Gandaki/Narayani, Karnali/Goghra and Mahakali originating from multiple tributaries which emerge onto the plains where they have deposited mega-fans exceeding 10,000 km2 (3,861 sq mi) in area, Secondary rivers in the Middle Hills and Mahabharat Range, from east to west the Mechi, Kankai and Kamala south of the Kosi; the Bagmati, Kosi and Gandaki systems which are variable flow through the dry season and finally the rivers in the Siwalik foothills which are mostly seasonal. [6]

My estimate of 70% of rivers containing algae leaves 31,000KM of the 45,000KM of river length and 140,000 km of small streams to farm and collect. This is where density per kilometer is important for cost work up.

**Yet unknown is if oil content of cold water Himalayan algae species. Typically cold water algae strains contain a higher concentration of lipids. We need identification of strains by a University Biology or Botany Department. Once lipid content is determined by Gas Mass Spectrometer (Gas Mass) testing a more exact cost work up can be given.

2.2 Cost Analysis

Weight of Algae Oil

One gallon of algae oil weighs (7.7 pounds/ 3.5 kg) and (3.79 liters = 1 gallon) each liter weighs 0.92 kg. One barrel of oil is (42 gallons/159 liters) so one barrel of algae oil is 146 kg. [7]

Production and Revenue Calculation by Weight

Calculating the algae collected is 40% oil by weight dried and you can press extract 80% of the oil from it, we can calculate 1000 kg of dry algae = 400 kg of oil (X) 80% = 320 kg oil from dry algae per ton would be expected. [8]

When we take into consideration one barrel is 159 liters and each liter weighs 0.92 kg we need 146 kg oil by weight to equal one barrel. Using the above calculation of 320 kg extracted per ton @ 40% dry weight than 2.2 barrels of oil can be produced per ton.

Today's spot crude oil price is $90.10 per barrel (X) 2.2 = $198.22 in sales. Goldman Sachs forecast delivery price for Nov 2011 is $110 per barrel continuing an upward trend. Calculating at $110 per barrel gives us $242 in revenue.

**It is important to note the type of expeller press and efficiency of extraction, results may vary depending on the age and engineering tolerances of the press.

Questions that need to be answered:

- What is the break even point of wages for villagers?
- What is the minimum quota per month per worker in kg or ton?
- What type of incentives can be offered to make people work more efficiently and effectively? The more you collect the more you get paid quota system.
- Ease of finding an end buyer for the biodiesel?
- Can a co-op be set up to buy dried algae by the kg from individual harvesters?
- Ease and reliability for record keeping of villager by weight in a co-op situation?

"Nothing Wasted, Everything Used"

I believe in the concept of "Nothing Wasted, Everything Used". With this in mind, I believe this is an appropriate flow chart do show benefit in every step along the way from start to finish. Algae is harvested by hand, dried and then pressed in an Expeller Screw Press. This creates jobs and provides additional income for dormant farmers awaiting the rainy season.

The harvesting and processing of algae to oil gives us valuable press cake which has two immediate uses:

- As an addition to anaerobic biogas digesters as co-digestion feedstock at the household level to improve methane gas output in both winter and summer.
- A substitute for charcoal briquettes in local blacksmith fires reducing tree consumption (*Algae Biomass Briquettes*)

Using algae press cake as a co-generation feedstock into a family sized bio-gas plant will help to increase gas output rates during the winter when cool weather slows the breakdown of materials inside the digester. During the warm summer months I theorize that the yield will be in access of what a family can use per day. If and when this occurs a second hose can be run to an additional home. The amount of biogas produced from algae mixed with cow dung was twice (344 ml/g dry algae) of that obtained from cow dung (179/g dry cow dung) alone. Also the duration of gas evolution increased with increasing proportion of slurry. The calorific value of the gas was (4800 K cal/m3) and the percentage of methane was 55.4%. [9]

The resulting Organic Fertilizer at the outlet from the bio-gas plant has been shown to increase vegetable crop yields by 30% than using cow dung alone. Farmers using biogas slurry enhanced by algae should have additional benefit.

This is another main reason I propose an algae biodiesel program from algae, in addition to oil produced by pressing, production creates a supply chain of algae press cake that can be fed into the family sized digesters. There must be a consistent supply of algae for an extended period of time to make a difference and for the villagers to see a difference.

2.3 LOGISTICS FOR COLLECTION, PROCESSING AND DISTRIBUTION

Collection and Harvesting of Algae

Large sites identified throughout this survey should be harvested and cultivated first. As we learn more about the how and where algae grows naturally in the Himalayan drainage basins and watersheds upgrades in harvesting techniques and prime locations will become more apparent as harvesting takes place.

Thinking into the future for next year, I envision flat river beds will be cultivated to allow for more drainage off of the flowing river into shallow pools created by moving a few stones into the right places. A few stones in the right position can create just enough slowing of the water to fill shallow spots all along the river with minimal effort or environmental impact. These small pools then become the grow out areas

Rice Fields are prime growing habitats if there is a flowing water source during the dry season. These fields could be flooded to a depth of 15cm and harvested on a frequent basis. I saw several possibilities around Lamjung and Hetauda districts. Another benefit in a rice field setting is that you cannot collect 100%, which means that algae will be present in the soil when crops are planted, fixing more nitrogen in the soil and increasing yield.

Workers will need screens, hooked rakes, and a flat space without debris in the air to dry the algae. This in itself is an aspect of solar power. We are using the sun's natural rays to dry the algae and that the sun initially provided algae with the energy to grow. They will also need bags to store the dried algae and a central collection point to bring the full bags. This is where having Nepali input and local knowledge is where I need assistance.

Pressing of Algae to Oil and Press Cake

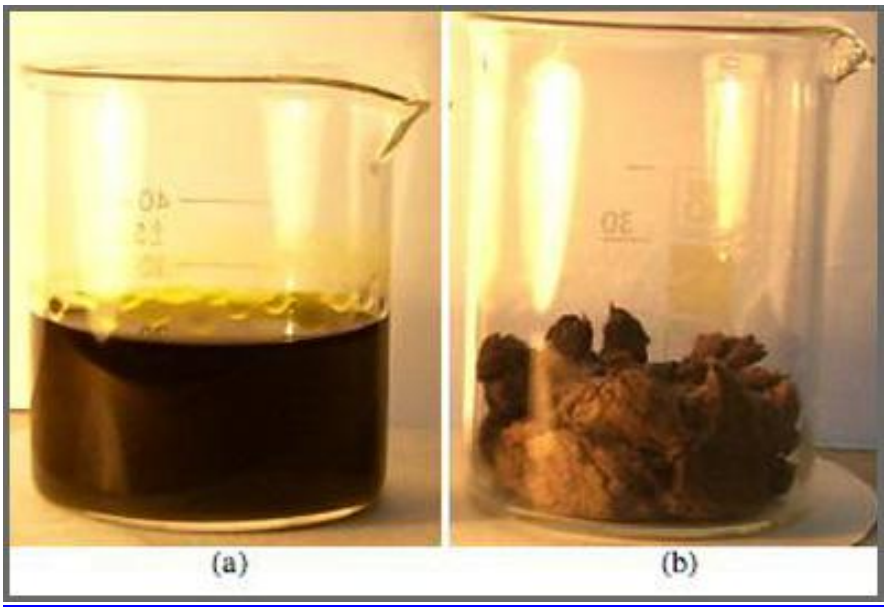
To save money initially a press should be rented by the day or the hour to press the amount of algae that has been collected. The resulting Algae Press Cake can then be distributed to families for their bio-gas digesters and blacksmiths could receive their charcoal briquette substitute.

Expeller Press to extract oil from algae

Oil Extraction

In the first step of extraction, the oil must be separated from the rest of the algae. The simplest method is mechanical crushing. When algae is dried it retains its oil content, which then can be "pressed" out with an oil press. Many commercial manufacturers of vegetable oil use mechanical pressing to extract oil. Since different strains of algae vary widely in their physical attributes, various press configurations (screw, expeller, piston, etc.) work better for specific algae types. [10]

- This is why it is so very important to have the strains of algae identified and oil content proven so we can use the best type of press to gain the highest yield of oil. See video [11]



Dried Algae to Extracted Oil

Processing of Biodiesel

One of the first steps is to contact other NGO's which also are involved with plant based biodiesel production. Nepal currently supports Castor Bean and Jathropa biodiesel projects. If other NGO's already have a processing facility built it would make sense to share the same space, expenses on materials and knowledge. This saves the initial costs for setting up a large scale Transesterification/Processing facility.

Removing glycerin from any plant based oil is called Transesterification and is a very simple, very safe process. You simply mix Lye and Methanol at the correct quantity to the oil and wait for the separation of glycerin to occur. Glycerin is itself a saleable by-product by the ton. [12]

Feedstock input could be shared, and with enough increase in daily/weekly deliveries, that biodiesel refinery could expand as well which would reduce costs by scaling up and splitting costs.

This gives the option to blend biodiesel into conventional hydrocarbon-based diesel and sold in the retail diesel fuel marketplace. Non-blended B100 could be sold directly to farmers for their tractors. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix. Obviously, the higher the percentage of biodiesel, the more ecology-friendly the fuel is.

- 100% biodiesel is referred to as **B100**
- 20% biodiesel is labeled **B20**
- 5% biodiesel is labeled **B5**
- 2% biodiesel is labeled **B2**

Algae oil by the 20 liter bottle

Finding Markets for By-Products

Glycerin- End buyers in Nepal.

Organic Fertilizer- If the amount of material produced is beyond what every local family can use in their fields.

Algae Press Cake- If the amount of material produced is beyond what every local family can use on their biogas digesters and the blacksmiths have more than they need.

Biodiesel- End buyers in Nepal.

There also exists the possibility to sell directly to the Nepali National Oil Company (NOC) or to a farmer co-op which will sell the oil directly to the buyer.

Resulting Development

Proceeds from sales can then be put back into the local community in the form of roads, schools, hospitals, town planning, energy efficiency increases in the community, trash collection, reforestation, Gravitational Vortex Power (GVP) micro-micro hydro for power generation at the local level for 20-25 homes off of one (GVP) plant etc…

International Donations could come with the understanding that this money is "Helping locals set up their own algae business". International Sponsors will want their company's name associated with our project for the "Green value and Good Corporate Citizen" image.

A local tractor will be used as a test vehicle to be driven on algae biodiesel. Engineers without Borders can supervise the testing and verify results. What would be nice is a local artist who would paint the tractor to the theme of sustainability and balance with nature and then use it in the fields. *Image below: Local farm tractor*

3.1 ALGAE SOURCES AND DENSITIES

Most common type of algae found in the rivers of Nepal

Algae at the river in Damauli

Around Kathmandu

Kirtipur Water Basin

Most towns in the Kathmandu Valley have a series of water collection ponds which have become full of algae as a result on under-usage. To collect this type of algae will require filters ranging in size from 10-50 micron and water pumps. The density of algae looks to be 1.5-2kg of dried material per cubic meter of water. There are also algae in swimming pools around the city during the winter cold season that could be harvested. This is an option later down the road when the wild harvest program is up and running there will be extra funding for harvesting with filters and pumps. **What I am suggesting first is that large river beds are a good target for large scale hand harvested river algae.** *Image below: Rivers on the Tibetan Plateau near Lhasa*

From the airplane over Sipaghat

Idea of using the riverbed to create algae grow out areas by redirecting water flow

The river bed at Damauli

Large tributaries definitely contain multiple metric tons of algae per kilometer, but let's not forget that smaller streams contain algae as well. These would be the easiest to farm as it only involves placing stones at the correct distances redirecting water flow and you can create perfect growing conditions by creating long finger pools. It's a basic recreation of the same conditions to allow more algae to grow naturally.

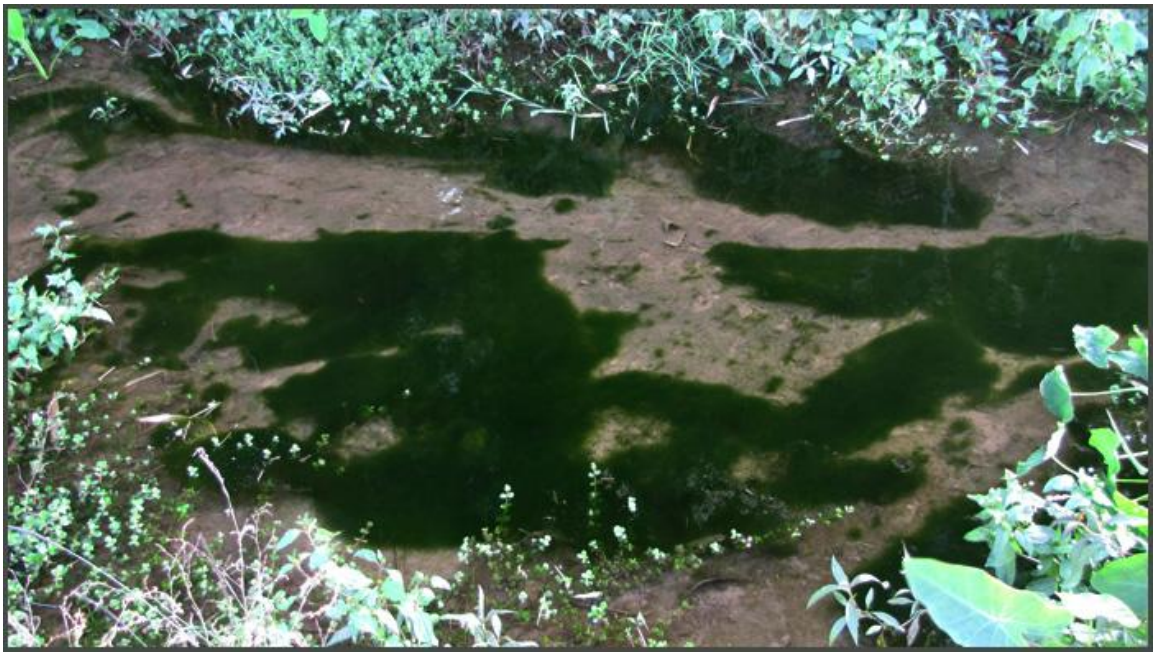
Algae in finger pools and river banks at the bridge in Damauli

Steeper boulder river algae Lamjung Area

Finger ponds off of tributary river Lamjung Area

Rice field irrigation streams Lamjung Area

Devi Falls Area close to Pokhara



Algae in a small stream near Hetauda

Satellite photos verify there is algae in large concentrations along fanned out riverbeds near Tal Chowk

Algae in small stone riverbed near Tal Chowk, this grow out area can be expanded

River bottom of small tributary at Tal Chowk

3.2 Cultivation of Riverbeds around Tamaghat to Create Grow Out Areas

Small rock and earth dam at Tamaghat

Small rock and earth dam at Tamaghat

Small rock and earth dam at Tamaghat

Very high densities per kilometer can be achieved by terraced cultivation of the river beds

Small tributary cultivation near Tal Chowk, Pokhara area

Small tributary cultivation near Tal Chowk, Pokhara area

Terai Region dry riverbed that can be cultivated for algae by the Square Kilometer

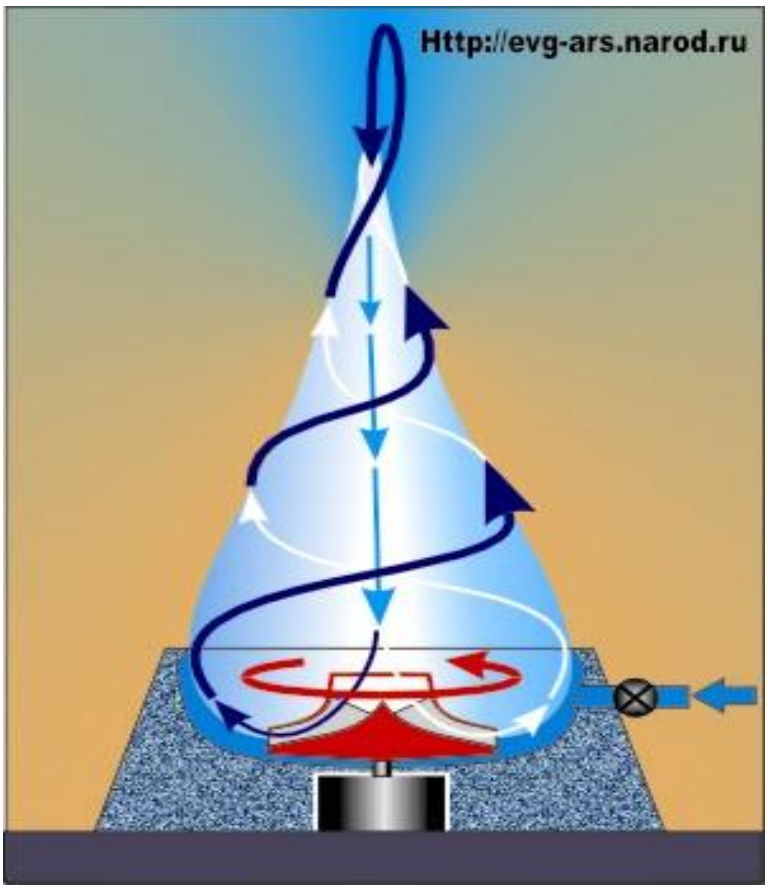
Near Chitwan Park in the Terai, UNLIMITED POSSIBILITY

(4.1) The blacksmith profession is alive and well in Nepal. Hand cranked fans funnel air, giving life to burning charcoal and red hot metal. As of December 2010 one bag of charcoal (30kg) costs 800RP and this blacksmith on average uses one bag every 4 days and when he is busy, one bag every two days. I asked him where the charcoal comes from and he answered “The forest”.

Algae Biomass Briquettes being burnt in a blacksmiths fire

Resulting glass coals from extremely high temperatures

5.1 Gravitational Vortex Power



Gravitational Vortex Power Generation

Zotloterer Gravitational Turbine

Production 57,000kW in the per Year

Finished Power Plant

6.1 Summary

In this report I have shown the possibilities of collecting wild harvested Himalayan river algae on a scale large enough to produce algae biodiesel to supplement the national fuel delivery chain. Cultivation by moving stones to divert water and create long finger pools which become algae beds, helping nature by creating the perfect environment for more algae to grow naturally is known as alga-culture and can be taught across the country so in the following years algae can be grown and harvested on a massive country wide scale.

Proceeds from sales can then be put back into the local community in the form of roads, schools, hospitals, town planning, energy efficiency increases in the community, trash collection, reforestation, Gravitational Vortex Power (GVP) micro-micro hydro for power generation at the local level for 20-25 homes off of one (GVP) plant etc…

Long term goals are to create a system of algae growth and harvesting that improve the economic conditions in rural districts that benefit the impoverished. Money saved from lower fuel prices and monthly income from algae collection can increase their disposable income and purchasing power. This will allow money to be used in ways that improve rural resident's lives, from health, sanitation to education and everything between.

This project can then be replicated country wide with a cut/paste approach from river system to river system. The impact will be far reaching and it allows local people in their local area to utilize local resources that are unused to generate income during the dry season when income levels are at there lowest.

Start-up costs are minimal in that collection/harvesting of algae requires nothing more than wire screens by the square meter for 50rps and some hooked rakes 100rps plus some rice bags 60rps for storage of dried algae. Oil presses can be rented instead of bought and we can look for an international donor to provide a press free of charge for positive corporate public relations and a green image.

Timelines for start-up are instant, the algae is in the rivers right now going to waste, if I have the human resources I need we can produce the first oil within one week. It will take 1-2 days to collect a few hundred kilograms, 2-3 more days to dry it and one afternoon to press it once we have located a press. We can pay the workers by the day at first to collect algae from the rivers after a supply chain is established we can buy it from independent collectors by the kg in a co-op setting. The co-op can then sell directly to farmers for their tractors or the co-op can sign a delivery contract with the National Oil Company (NOC). When this happens, those involved in the project can share in a percentage of income generated.

6.2 Budget and Resource Proposal

What Resources are needed from Choice Humanitarian Nepal

- A one year commitment to see the project through at all water levels throughout the dry and monsoon seasons.
- Topographic maps of river drainage basins and watersheds by district, village or zone to target selected high output areas first.
- Local Human Resources and arrangement of payment for workers salaries, co-op development, and purchasing of equipment used for collection.

- Algae samples identified (Taxonomic Identification) by the laboratory of a Botany Department from one of an internationally recognized Universities in town.
- Identified species need to be photographed on a microscope slides.
- Gas Mass Spectrometer (Gas Mass) test of algae to determine lipid content.

- Arrangement of an oil press either domestically or internationally through a donation.
- Creation of Educational Lessons on environmental protection and biodiesel needed to accompany this project.

- Heat gun to measure temperatures in blacksmith fires with a charcoal/algae biomass briquette mix compared to charcoal alone.
- Monitoring of algae in biogas digester to measure increased methane output. The help of BSP Nepal or institutions with gas pressure monitoring equipment.

- A stipend for myself to cover living expenses and small costs on site related to the project monthly for a one year period. I will also be publishing stories, updates and reports to oil journals, sustainability magazines, renewable energy websites and publications. I will also be on-site as much as I can to photograph the process and detail optimum conditions for algae grow out areas.

Cooperation and Advisors

Engineers Without Borders, Yamaha and Honda Generators, Tractor manufacturers, Algae Biodiesel Companies, Universities involved in algae fuel research, Business Professionals (Retired or Working) that have an interest in this project, National Renewable Energy Labs, Department of Energy, Other NGOs working on biodiesel or environmental projects with renewable energy The National Algae Association (NAA), The Algal Biomass Organization (ABO) formed by Boeing Commercial Airplanes, Global air carriers Air New Zealand, Continental, Virgin Atlantic Airways, and bio-fuel technology developer UOP, a Honeywell company, will be the first wave of aviation-related companies, Nepal Airlines and the list is far more extensive.

7.1 Closing Comments

From my point of view, this type of publicity will begin to establish that Nepal is indeed on the way to re-inventing itself after these last years of turmoil. When this type of fuel program reaches a majority of Nepal and the average citizen understands that Nepal is no longer as reliant on India for fuel imports a new form of positive "we can work together and produce our own fuel for Nepal" attitude should form and with that a new national identity of co-operation can form. *Renewed Social Economics=Renewed National Identity*. Along that same line is that a stable fuel source equates to a more stable society that can develop. *Stable Energy=Sustainable Development.*

Now the billion dollar question? If we consider Nepal oil imports at 20,000 barrels per day from India in 2011 and today's prices are $90 per barrel, that's 1.8 million dollars per day. If we multiply that by 365 days then we get $657 million per year. I am proposing reversing the concept of paying for oil to producing internally this amount plus exporting the excess to India. What type of resistance are we likely to encounter? The pie is much bigger, not million but billions of dollars in redistribution of wealth throughout the country and new alignments to political interests. Can this project be done safely?

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