OpenPower Nepal

Open Source Technology for Rural Nepal

Senior Project by Urs Riggenbach, Spring 2012
College of the Atlantic

Summary

The OpenPower Nepal project aimed at designing and implementing a framework for renewable energy access that can be assembled and maintained locally.

I built it at the Maya Universe Academy, a primary school that provides free education in rural Nepal.

This document serves as a report of what happened as well as a guide to aid replication of the implemented technologies. Included is the funding process, planned and actual budgets, concepts, and building plans.

Not all the parts of my project were finished during my time in Nepal, but all the modules implemented are successfully producing energy for the school.

I hope the plans and experiences in this document will serve others striving toward energy self-sufficiency. For this reason, this document and the ideas and plans contained within it are released in an open source manner.

A big thank you to all the donors and advisors along the path. Without you, this project would have not been possible.

I am continuing my work on open source technology in the realm of renewable energies. Stay tuned to developments and campaigns at www.solarfire.org.

Release Date: Friday, May 25, 2012

Table of Contents

Foreword

Over my past four years at College of the Atlantic I wrote about projects and people who do stuff. After three years of that I felt inspired to become one of them.

With this project I tried to see what was possible. I didn't know whether I could succeed, but if I could, that would mean that one guy with simple skills could change the world.

If these skills led to success, it would then be my obligation to teach others these skills so that they can change the world, too.

This document does exactly that: teaching you the skills it takes to follow my footsteps.

Let me clarify my human ecological viewpoint according to which I wanted to change the world.

Introduction

Imagine a world in which building plans — the information used to produce goods — are freely available for everyone to study and put to use. Everyone using these plans is invited to maintain these plans as a knowledge commons.

This revolutionary approach of peer-production is already happening; it's virally growing and has already produced some eye-opening technologies. These open source technologies are amazing because they have been developed *by* people *for* people without corporate interests. They usually cost less than their commercial counterparts, but are not necessarily more low-tech. Some of the agricultural machines are up to eight times cheaper than their commercial counterparts.[1] Additive fabrication of plastic objects done with so-called 3D printers rely on complex digital technologies and yet they have been developed and open sourced by users.[2] Since they create these technologies to serve their personal need and also believe that what serves them can serve others, they share those plans.

These technologies are built in the simplest way using the simplest materials. Unlike commercial cars that need specific replacement parts, *open hardware* relies on general parts. The diesel engine in open source cars and tractors is a simple block, a module, that can be replaced later on with an electric or steam engine.[1] If more power is needed, two such modules can be connected in a series to double the power (in the case of hydraulics). Modularization also makes the development process easier by splitting the developers into smaller module-based teams.

Not everybody will contribute actively to the development, but every person that builds a machine spreads the technology, ultimately getting more people interested, some of whom will contribute. The same principle applies to Wikipedia: a minority contributes expertise, a majority benefits.

---

[1] "Key Features of the GVCS." Open Source Ecology. Web. 24 May 2012. <http://opensourceecology.org/wiki/Key_Features_of_the_GVCS>.

[2] "RepRap." RepRap Wiki. Web. 24 May 2012. <http://reprap.org/wiki/RepRap>.

The reason why I am not scared of corporations taking all this open information and turning it into proprietary technology is that these technologies have been developed with a whole different underlying philosophy. It is the practice of a corporation to exclude other's access to their information, whereas in the open source approach, everybody has access.

Not only patents protect proprietary technology, it is often the technology itself that is designed to be too complicated to replicate at a small-scale. A lot of human creativity is wasted on creating technology that is purposefully hard to copy and understand, just so that a company can maintain their production monopoly. Are innovations — such as the terminator gene, throwaway goods, proprietary file types or breaking light bulbs — really technological advances?

I believe that technology does not necessarily need to be complex. Today, even if a technology is easy to use, it still is very hard to build and impossible to maintain locally if parts need to be shipped in from elsewhere. Already light bulbs that never break have been developed. The reason why they are not on the market is because nobody wants to produce them. But if you were to produce a light bulb for yourself, you would try to produce one that lasts forever. Instead, time and money has been spent to perfect the timed breakdown of lightbulbs. Technology hence is not what it could be and, in my opinion, not what it should be: simple, modular, compatible, and open source.

I have been following the trend of open source technology for years now. I first observed a whole ecosystem of software running on Linux, the open source operating system that comes with open source software such as Firefox and LibreOffice preinstalled. The fact that a loosely coordinated bunch of hackers could produce a stable operating system and software that runs (unnoticed to most users) on more that 60% of all web-servers amazed me. Because this software was made *by* people *for* people, it was faster, more virus resistant, modular and integrated, in addition to being free. And all of this through voluntary contribution of tech-savvy hackers.

Could peer-production be taken to the next level — moving from *soft*ware and content to *hard*ware? Could we collaborate on the building plans of technologies that provide us modern day comforts? I found out that people had already started doing this.

I decided to join this movement, because not only is access to information a way to empower humanity in general, access to building plans of technologies also enables *local production* — leading to more local and decentralized economies.

In a time where peak oil production and climate change may limit transportation and global trade, enabling local production is key. Such economies can produce locally from imported or recycled raw materials, such as metals or wood. Currently, finished products, such as cars, are produced in one place and then shipped to another place to be sold. Last year, the last solar photovoltaic company in the US shut down[3] because panels can be manufactured elsewhere more cheaply. Globalization is destroying local economies. As cheap transportation as we know it is coming to an end because of peak oil, local economies will have to be reestablished to serve humanity's needs.

Local economies are also more accountable due to their short and comprehensible supply chains. Because the trade can be understood, stakeholders have more visible roles and gain a voice. This creates incentives for sustainable means of production as stakeholders in the economy would have to face environmental degradation themselves. Currently, those problems lie somewhere down a globalized supply chain, probably in a developing country with loose environmental and social regulations.

My hope for the future is the exponential growth of *global collaboration* on open source technologies, and *local production*, in small-scale, resilient economies. This would minimize global trade, create incentives for socially and environmentally sustainable means of production, and encourage creativity at a local level. It would also be a more beneficial way to harness human intelligence.

The technological foundations for such a future have been made. The tools such as software and knowledge on all academic subjects are freely available. Local people have skills in mechanics, fabrication and electronics. Open hardware projects have successfully developed farming-equipment, cars, 3D printers, computer-controller (CNC) routers, solar concentrators, hydropower turbines, and decentralized phone networks, enabling technological breakthroughs in communication, renewable energies, fabrication, transportation, and food production.

---

[3] "Hard Times for Solar Companies." Energy & Capital. Web. 24 May 2012. <http://www.energyandcapital.com/articles/evergreen-solar-bankruptcy-solon-se/1715>.

With this project I hope to contribute back to the growing pool of open source knowledge from which I took my inspiration, tools and ideas in the first place.

But as Lewis H. Michaux said on The Black Power Mixtape,

"[...] Knowledge is power, [... but] if you don't know and ain't got no dough, then you can't go, and that's fo' sho'."

To get started I needed some *dough* and *a place to go*.

Background

The Project Site | MayaUniverseAcademy.org

A Youth Movement for Free Education

The Maya Universe Academy (MUA) located in rural Nepal aims to be a model-school for self-sufficiency. One year ago Manjil Rana, a United World College graduate, returned to his hometown in the Thanahu District of Nepal and started a school that provides free education. To build the school Manjil asked for the help of the community. In his money-free model, parents contribute two labor days per month to the school in return for their children's education. The labor is necessary to construct buildings and maintain the campus with its farm. This year the focus of MUA will be to establish an additional classroom, and to grow their farm to the point where their whole operation is financially sustainable. A few weeks ago a team went out to assess a new location in the Mount Everest region. Plans for opening three more schools have been made. To spread their model they are in need of hands-on, committed volunteers for teaching and agriculture.

First Grade Students at Maya Universe Academy (MUA).

A shed overlooking the hills nearby MUA.

I knew Manjil from my time at the *Mahindra United World College* in India (2006-"08) and the *College of the Atlantic* in the United States ("08-"12). When I found out about his school, I thought that not only should it be a model for free education through sustainable agriculture, but it should also demonstrate and teach sustainable, open technologies that can be built cheaply, using local materials. Manjil showed interest in having a solar concentrator or micro-hydro system on his campus for electricity generation and food processing such as milling. The technology was simple enough that he eventually could teach it to his students and empower them to access renewable energies. Together with sustainable farming, these kids would be empowered to run a whole local economy, even in times of national and global fossil-fuel shortages.

The morning circle at MUA.

I thought his school could benefit from such technology so I decided to do my senior project there. In Asia, material cost would be lower and a working system could easily grab the attention of NGOs that would want to spread the technology further. Besides, on my way to Nepal, I could stop by the renewable energy business TinyTech, that together with the organization SolarFire.org, had developed a solar concentrator that enables cheap access to solar energy, all in open source.

Architecture class at MUA.

Open Source Solar Concentration | SolarFire.org

Reducing Pollution, Energy Poverty and Helping Solve the Thermal Problem

I learned about the solar fire technique during a visit to Open E Farm in rural Missouri, United States. Project leader Marcin Jakubowski, PhD, of Open Source Ecology (OSE), is developing the Global Village Construction Set: fifty modular technologies that enable a healthy, comfortable lifestyle. Included in the set are plans for a tractor, an earth brick press, an electricity generator, a steam engine, hydraulic systems, a wood gasifier, and many other technologies that are the base for current and future civilization.

Their machines are generally eight times cheaper than their corporate alternatives.[1] To attract collaborators and increase usability, these technologies are modular and are built to be maintained locally and to last. During my visit, I helped develop and build prototypes of hydraulic tractors. These open source projects keep up to date on the open hardware movement.

They told me about Eerik Wissenz from Finland, who developed a technique for solar concentration called solar fire and documented it on his website SolarFire.org. Solar concentrators use reflecting mirrors to concentrate sunlight into a smaller area, resulting in sunlight multiple times stronger than normal. The resulting heat can be used directly to power heat-intensive processes such as melting metals, roasting, drying, pasteurizing, distilling, baking, char-coal making, etc. If the heat is turned into steam by means of a boiler at the focal point, the resulting steam provides is not only easily piped to appliances, it also results in pressure that can power a steam engine, resulting in motion. With steam engines, mechanical machinery or electric generators can be run. And all of this produced with cheap, local, non-toxic, low carbon footprint materials.

I conversed with Eerik and found that it was possible for me to meet him in India at TinyTech, the business at which he produced a solar concentrator in the past year. That was a solar concentrator that concentrated 32m^2 of sunlight down to 1 square foot for steam production. This year he was going to return and build the first 90m^2 concentrator that could power a 10hp steam engine — enough to run most industrial machines found in the developing world.

Open Source Hydroelectricity | GlobalAnchor.org

Providing Hydropower Solutions for Rural Electrification

SolarFire.org is not the only project focussing on open source renewable energies. Ino Fleischmann from Germany has been working in Nicaragua to bring renewable energies to rural areas. He too develops his technique openly to attract collaborators all over the world. Similarly, his technology is cheap (one dollar per watt) and can be built locally. If the water resources at MUA were sufficient, I could implemented his hydropower-system on a new continent.

Ino also said that he has connections to people who were working on open source wind energy. With solar fire and micro-hydro however I thought that I had enough options for implementation.

Both Ino and Eerik see clearly that if we want to overcome the energy and climate crisis due to fossil fuel addiction, we all have to move to renewable energies, and an open source approach can facilitate development and decentralized implementation all over the world quickest. Currently, the only commonly used small-scale renewable energy technology for electricity are solar photovoltaic panels. Such panels are manufactured in a very energy intensive way and then shipped across the globe for installation. It can take up to four years for a panel to give off as much energy as went into manufacturing it. Both Ino and Eerik stated, that they will provide plans and guidance to me in case I implemented their technology in Nepal.

I wrote up my project, and named it “OpenPower Nepal” — “Open” referring to open source, which together with “Power” reminds of the word empower, illustrating the overall aim of the project; to empower through open source technology.

Project Description | OpenPower Nepal

Excerpt from the project proposal, fall 2011.

My senior project is about the construction of an electricity generating technology at the Maya Universe Academy (MUA) in Nepal. The project utilizes a modular framework for electricity production that can be adapted to site-specific needs. Upon my arrival at MUA, I will assess the site in detail and decide which resources to harness, and hence which modules to build.

This, however, is not just about bringing money to a community and establishing infrastructure. The aim of the project is to make all building plans and documentation public so that other communities can adopt and adapt this work.

By taking on this project, I am becoming my own subject as I am joining the open-source movement. Tracking the challenges and learning-experiences that come with implementing a technology at a local level is an integral part of my senior project. Upon completion of the *project, I intend to contribute my plans to the open-source community, thereby gaining further insights into the collaboration process.*

There are two parts to my project. First, I am going to visit the solar fire project in Rajkot, India at TinyTech, a business that provides alternative energy systems in collaboration with SolarFire.org, a Finnish organization. Eerik Wissenz of SolarFire.org is the head engineer of the technology as well as an open-source advocate. Mr. V K Desai, the director of TinyTech, has invited me to visit his factory. I will spend nine days there: learning about the solar fire technology and exchanging ideas with these leaders in the field of open hardware for renewable energies. I also want to get their input for adapting the technology to MUA. Eerik has already helped me frame a budget and has provided me with the specifications for the technology.

On February 3rd I will travel to Nepal and visit the MUA school. After an initial site assessment, in which I assess the resources and decide which resources to harness in what ways, I will begin ordering the materials and construction. If the solar fire method is chosen, this will also be the time to officially order a steam engine from TinyTech and organize shipping to Nepal. I have been in contact with various businesses and NGOs in Nepal to prepare for the sourcing of the parts and materials.

During that time I plan to post pictures of my progress on the project website through which by the project start, I hope to have raised the $4100 needed for construction-materials.

Coming back to COA I will write up my project report and publish the plans created for the construction of the technology in an open-source fashion.

Open Source Electricity Framework

I moved ahead and developed a conceptual framework that outlined all the options I had for implementing renewable energies at MUA. Through consultation with Manjil, we agreed that electricity will be the main aim of the project, although powering a mill should be the next step. In developing the framework, I relied on my knowledge of sustainable technologies, open source projects and resources that I could tap during the construction. I identified five possible pathways for electricity generation, many of them interconnected through shared infrastructure.

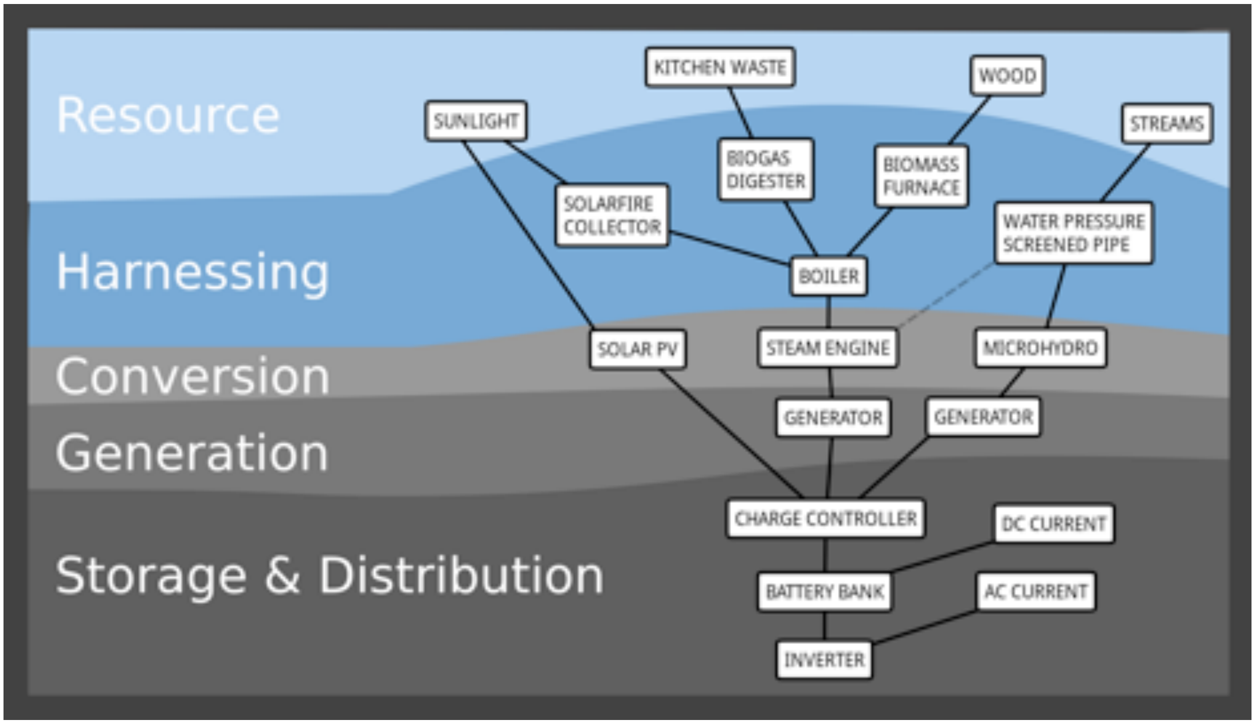


Diagram 1: The Framework harnesses multiple renewable energy resources through a variety of modules.

All pathways feed into the charge controller that feeds the battery bank from which AC and DC current flows to electric appliances such as lighting and computers.

The pathways are (1) solar photovoltaic, (2) solar concentration connected to a steam engine and an electricity generator. Human, animal and food waste could be turned into (3) biogas in a digester, and the biogas could be turned into heat to create steam for the steam engine too. Wood, or biomass such as agricultural waste (rice husks, leaf litter, etc), can also provide heat for steam production by means of a (4) biomass heater. If water resources would be available, a (5) micro-hydro system could be built. For all these pathways I had contacts in the field of open hardware that agreed to help me develop and adapt the technology to Nepal.[4]

During my project, I have expanded my knowledge of renewable energies. If I was doing the framework again, I would add some additions to it. I learned that biogas can be turned into electricity with a propane-based generator directly.[5] This would bypass the boiler in

[4] See Appendix: List of Resources.

[5] Stichting Veldwerk. "Actueel Hamro Gaun Eco Dorp." 28 Apr. 2011. Web. 24 May 2012. <http://www.stichting-veldwerk.nl/en/what-we-do/current-projects/hamrogaunecovillage>.

the diagram, which would increase efficiency. I also could add wind as a resource. My concept of wood also expanded into biomass because I learned about briquettes made from agricultural waste that burn twice as efficiently as wood at a local NGO in Nepal.[6] Nonetheless, the framework served as a practical way for me to illustrate my options and explain my plan.

[6] "FoST Nepal." Foundation for Sustainable Technologies (FoST) Nepal. Web. 24 May 2012. <http://www.fost-nepal.org/about.html>.

Timeline

Overview

The below diagram shows the timeline of my OpenPower Nepal project. The different phases are elaborated below.

Diagram 2: Timeline illustrating the different phases of the OpenPower Nepal project.

Online Fundraising Campaign

Fall 2011 – Winter 2011/12

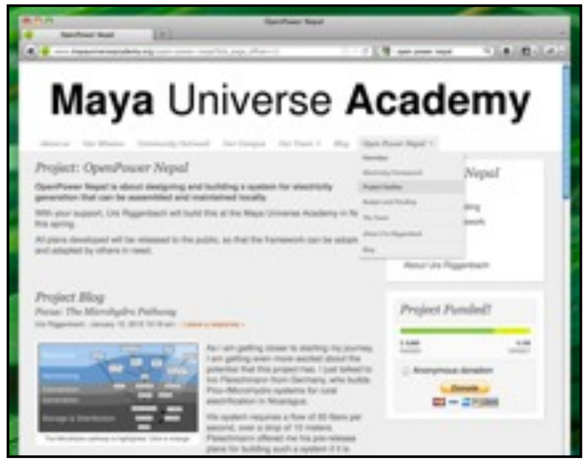
I needed money for materials. My calculations together with Ino and Eerik suggested more than $4000 was needed for building just one of the pathways outlined in the framework, and even more if I were to implement two pathways. This was clearly more than what I could ask my family and immediate friends to contribute.

I decided to publicize my project on the internet and raise money from supporters of my cause. Since I was going to do all of this at the Maya Universe Academy, and since I was the webmaster of their website, I decided to use a section of the site for my project.

Using Wordpress,[7] a free and open source blogging tool, I implemented the blog and a few pages with my planned budget, timeline, and concept.

[7] See Appendix: Open Source Software Used

Then I wondered how I should collect money. There are many online fundraising websites that enable crowd-funding, and they provide nice widgets. Kickstarter.com seemed an especially promising platform. Every project on Kickstarter has a financial target and a set deadline, and if the pledges collected from people pass the fundraising goal, the money is deducted from the supporters' accounts.



The project website featured a blog, and project details, as well as information on ho to donate.

But Kickstarter requires that special rewards be given to supporters of different sums of money, and that was not my philosophy. Everybody, even those who would not support my project, should get the reward I offered: the open source building plans.

Their website also is not multilingual, which would pose a problem once I wanted to start raising money in Switzerland, and the mode of payment was through Amazon Payments, which is something most non-Americans are unfamiliar with. I needed something based on a more international service, such as PayPal.

I decided to make my own multilingual, multi-checkout fundraising widget that would show the goal and progress of the campaign, just like I saw on Kickstarter. I would then be able to integrate this widget on other websites and draw more people in.

I developed a widget for integration on other websites.

To do this I used the Donation Can[8] plugin for Wordpress, and tweaked the theme until I got a standalone widget version that could be integrated on other sites.

[8] See Appendix: Open Source Software Used

I also created a dynamic graph that showed how much of the budget is covered. I posted updates to the slowly growing Facebook page.

This widget showed the state of the fundraising campaign and how much of the planned budget was covered.

I posted project descriptions and updates on various other sites. Donna Gold from COA wrote a press release for me, Eerik Wissenz of SolarFire.org let me post on his site. I also spread the project on United World College alumni sites. To test whether I publicized my project well, I typed "OpenPower Nepal" on Google, and found my site to be the first entry. All other entries were places where I or other people posted about my project.

People looking for my project online could find it.

Then I wrote lots of emails to my social networks at COA, UWC, Yestermorrow, and in Switzerland. I also contacted interest groups on open source hardware such as Open Source Ecology Europe and individuals in the renewable energy sector in Switzerland. Slowly, the amount of money came together. By the time I reached MUA, the project was funded.

On the 8th of February, the fundraising goal was reached.

The first two donations I got from unknown sources. That was very exciting. Then I got a grant from COA's new president Darron Collins. In Switzerland I worked and added the income straight to the campaign. Much came from the COA community and UWC friends from the past. I was also surprised by the support of the open source community. Previous donors to the Maya Universe Academy also supported my project.

Visiting TinyTech in Gujarat, India

January 25th – 3rd of February 2012

After a few days in Mumbai, I left for Rajkot, Gujarat, the birthplace of Mahatma Gandhi. A ten hour train ride took me into the heart of this vegetarian city which tourists rarely visit.

West of this two million people city is an industrial area where there are many small to mid-size factories that manufacture diverse parts used in mechanics, thermal engineering, and other industries.

Rajkot, Gujarat, India, is located a ten hour train ride from Mumbai. Map Data © Google 2012.

It is in that industrial park that TinyTech has the bigger of two production plants. On the day I got there, I went straight to the building site where Eerik Wissenz and V K Desaiji were just completing their first 90m² solar concentrator.

This is the 90m^2 solar concentrator by TinyTech.

Over the next days I helped in the construction of the solar concentrator and got to know them much better. Both are amazingly inspirational beings. Desaiji is a Gandhian, and both Eerik and he believe in decentralization of power, knowledge and production.

Making a connection with Desaiji enabled me to get some offers on his steam products and estimates for how long the manufacturing and shipping would take. Eerik and I talked extensively about humanity’s future of peak oil and climate change and how solar fire and open source peer-production could play a vital role in safeguarding human survival in a peak oil scenario. Eerik also showed me some new ideas for simplifying the solar concentrator and told me the history of the current innovations. Soon enough it was time to depart for Nepal.

Reaching Nepal

February 4th - 6th 2012

I reached Nepal on the 4th of February. It was amazing to finally be in the place where I would do my project for the next two months. Before I went to the school, I had one person in mind that I should meet: Muni Raj, a local engineer. I got in touch with him through Alex Zahnd, who has an NGO supporting people with renewable and appropriate technology in rural Nepal.[9]

Damauli is located a four hour drive away from Kathmandu, Nepal's capital. Map Data © Google 2012.

At his place he showed me the simple, sustainable energy technologies he had been working on over the past 20 years. He had experience in designing efficient wood-stoves, heat storage using the calcium bicarbonate cycle, solar tracking, and other electronics equipment such as Maximum Power Point Tracking charge controllers (MPPT), different inverters and charge surveillance and recording devices.

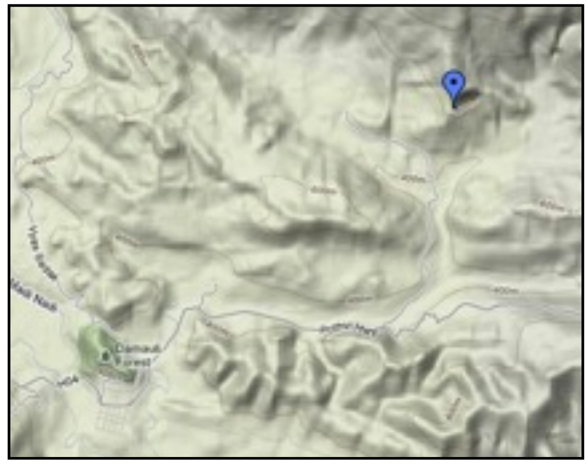
The father of the founder of MUA, Govardhan Rana, also got me to meet Niraj Shreesta, who owns SunWorks Nepal. He is an active engineer working on solar heating for agricultural (solar drying) and water (solar hot water) use, solar concentration for electricity generation (Combined Heat and Power Systems, CHP), and many other heat and renewable energy related technologies.

[9] Rural Integrated Development Service (RIDS) Nepal. <http://www.rids-nepal.org>

Site Assessment

February 7th - 9th 2012

After 2 days I left for the Maya Universe Academy. After operating for one year, the school has established its own livestock consisting of chickens, ducks, pigs and a cow. Gardens surround the campus where vegetables for domestic consumption are grown. The chickens and ducks are just starting to lay eggs. The school also plants rice paddies with the help of the parents and volunteers. Together with the help of students, MUA also planted banana and papaya trees this spring.



MUA is located a two hour walk or a 30 minute bus ride from Damauli, a town on the main road between Pokhara and Kathmandu (Prithvi Highway).
Map Data © Google 2012.

My site assessment showed that there were no abundant water and wood resources, but plenty of sun. In the dry season, water has to be hauled from a nearby spring or pumped up into storage tanks from a neighbor owning a well. Based on these facts I decided to go solar. I moved ahead with the following action plan:

- **Pathway I:** To collaborate with Muni on a solar photovoltaic tracker for domestic electricity uses. He would provide me with all the materials I needed.
- **Pathway II:** Then I looked over the offers I had from TinyTech. I definitely needed a steam engine and electricity generator to put the solar concentrator to use. TinyTech also manufactures biomass power plants that use agricultural waste or wood to create steam and run the engine. So instead of just ordering a steam engine from TinyTech, I decided to implement the biomass pathway too.
- **Pathway III:** I then could focus on building the solar concentrator in Nepal and hook it up to the existing steam grid provided by TinyTech's biomass-steam power plant.

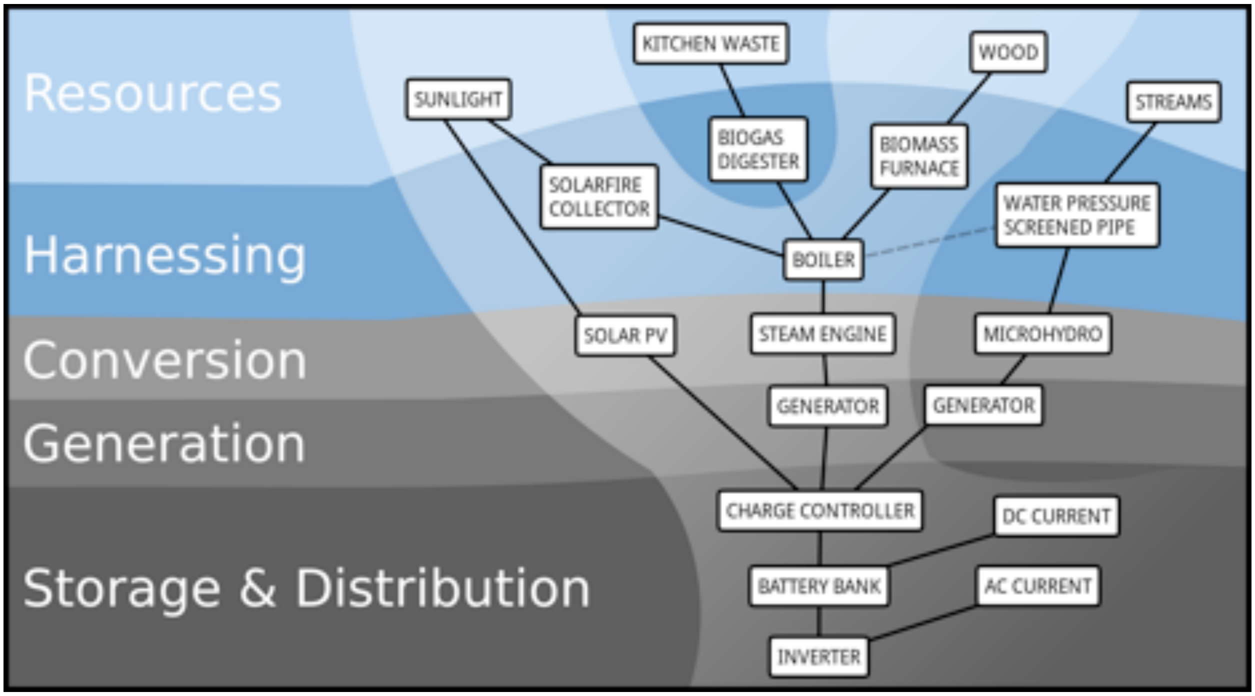


Diagram 2: After the site assessment, I decided to implement all the highlighted modules.

That approach would allow me to run and test the steam engine with biomass before finishing the solar concentrator, so the power of steam could be demonstrated right away. The aim of the project, therefore, was to implement the highlighted modules in the diagram above.

Pathway I | Solar Photovoltaic Tracker

February 10th - 3rd of March 2012

Excerpt from the blog:

Dear followers, we have completed Pathway I of the OpenPower Nepal project. Two days ago, my brother from Switzerland joined me in Kathmandu. The same day we went by Muni's place, the engineer who develops solar PV systems for rural Nepal.

With the help of my brother and other volunteers at the Maya School, we dismantled a solar tracker, loaded it in our jeep, and crossed the Kathmandu valley to spend the night at Manjil's father's place.

The next day we travelled back to the Maya school. On the way we picked up two new volunteers from France and the US. Five volunteers from Singapore reached the school the next day.

In a day we erected the solar tracker and connected the charge controller, as well as an AC inverter. The capacity of our current system should provide enough energy for lighting, charging phones, and running laptops. The system can be upgraded with two more panels as all other components have been sized to accommodate additional solar panels and increasing loads.

The school needs electricity for lights, music and laptops. During my brother Christian's visit, we rewired the house to an international standard (my brother is a professional electronics wiz). We implemented a DC circuit for efficient LED lighting. We expect the energy consumption for lighting to be less than 40 Watts when all the lights are switched on. There is internet access through the cell phone network, so volunteers often want to operate a laptop. Music is another energy consuming appliance not to be overlooked. Most importantly, cell phones will be charged with the solar energy. Muni provided me with a cell phone charger that runs on DC. At night, the AC inverter can therefore be switched off, while lighting and phone charging still work directly from the battery bank.

Installing the mast on top of the roof with the help of a student.

Table 1: **Energy Consumption at MUA**

Appliance	Watts [W]	Hours [h]	Watt Hours [Wh]
Lighting	40	4	160
Music	70	4	280
Laptop	60	4	240
Cell charging	20	8	160
Total	190	20	840

The solar tracker we installed can hold four panels of 75Wp each. We installed two, resulting in a peak output of 150 Watts. Every morning, the tracker would still face west, where the sun had set, but as the sun rose, at about 7am, the tracker started focussing on the sun in the East. Solar tracking creates about 30% more output from the same panels. In the calculations below, I assume about 6 hours of peak production. In the early to mid dry season, there is often fog in the morning, limiting the amount of sunlight drastically. The hours between 10am and 2pm are the most efficient, and the hours before and after will show an energy output below 150 Watts.

Table 2: **Energy Production at MUA**

Solar Tracker	Total Capacity [W]	Hours [h]	Watt Hours [Wh]
As installed	**150**	**6**	**900**
Additional panels	**300**	**6**	**1800**

With the increasing amount of volunteers and activities in the school, the tracker can be upgraded to produce a total of 1.8kWh per day, which currently would be more than double the capacity needed. The tracker, battery bank, charge controller and inverter were sized to accommodate an upgrade to 300 Watts in the future. The peak output of the inverter is at 1.4kW. This capacity allowed me to use the solar energy to operate the skill saw and the drill while cutting plywood and drilling holes into concrete walls, etc.

The school is connected to a neighbor's house that has access to Nepal's main electricity grid. While there is sufficient electricity coming from the main grid in the rainy season, there is a severe energy shortage in the dry season in Nepal. That is because most of Nepal's electricity is generated in hydropower plants. Coincidentally, the solar panels work better in the dry season due to the clear sky. In the dry season, MUA gets about 16 hours of electricity per day from the main grid. Compared with the rest of Nepal, this is a huge amount. In the Kathmandu valley, it is normal to only have 6 hours of electricity per day. As energy demand in Nepal is rising, the amount of electricity available per capita is shrinking. I am expecting the energy shortage from the main grid to increase over the next few years as more and more villagers turn to electricity-hungry appliances such as refrigerators and TVs. The solar panels will enable MUA to stay off the grid in the future. With double the needed capacity after the upgrade, the solar system is likely to perform well even in the monsoon where only about 3 hours of sunlight per day can be expected.

Pathway II | Biomass Steam Heater

February 10th - 18th of April 2012

The biomass pathway consisted of a shipment from TinyTech in India consisting of a biomass heater that would consume 4kg of wood per hour for peak output, a three horsepower steam engine, a kilowatt generator, a condensator and interconnecting pipes, valves and belts. The output from the generator could be used to charge the battery bank, or be used directly as AC current.

The shipment also included some solar cookers that would allow for smoke-free cooking during the day. The total weight was just under a ton.

I asked Desaiji of TinyTech multiple times: “How long will it take for the shipment to Nepal?” — “About ten days”, he replied. — “Nice, so it should be there within a month.” I thought, multiplying whatever time he suggested by a factor three (I spend two years in India back in 2006).

To everyone's surprise, it took more than 80 days, meaning that the shipment only reached Nepal after I had left. So there was no chance for me to get my hands on a steam engine nor implement Pathway II. First, I made a mistake in the transaction details for the payment I made to TinyTech (I specified the recipient's name instead the name of his business in the transaction form). Both sides followed up with their banks, and after 10 days, the money was in its proper place. By that time, however, TinyTech was busy finishing another order to an African buyer. When they got to focus on my steam engine after a week, they had to solve some technical difficulties before they could pack and ship it. Therefore, the shipment was only put together after another 10 days. Still, it could have reached me in time.

The big delays were because TinyTech chose a slow but cheap transportation company that was very inflexible in speeding up the process. When the shipment finally go the the border a few days before I left Nepal, we lost some additional time reducing the import tax. In addition, there often are political strikes that shutdown the transportation system for days.

Moving forward

When I or someone else of SolarFire.org gets to Nepal, Pathway II can quickly be implemented, as the shipment is stored safely at MUA. This will demonstrate the power of steam. If wood is limited, as at MUA, the solar concentrator can run the generator or mill on sunny, clear days, and the biomass heater can enable operation on rainy or unclear days using agricultural waste briquettes[10] that could be manufactured at MUA.

[10] "FoST Nepal." Foundation for Sustainable Technologies (FoST) Nepal. Web. 24 May 2012. <http://www.fost-nepal.org/about.html>.

Pathway III | Solar Concentrator

February 10th - 18th of April 2012

The solar concentrator was the part that lacked the most time for completion. During my time I managed to adapt the solar fire technique to Nepal, mainly by simplifying its design and making it more low-cost. By the time I had to leave Nepal, I had worked out all parts in design and prototypes, but there was not enough time to attach all the mirrors and install the boiler.

Nonetheless, I was able to improve the initial design I had in mind, which should ease the development of the wheels-based method in the future. All the changes and plans developed are to be found in the “Plans” section.

Excerpt from the blog:

The design I developed was centered around local materials, buildability and being low-cost. Instead of going with a central mast from which mirrors are suspended, I decided to use wheels on flat ground, and a free standing boiler. The corner-pieces with wheels were purchased from Kathmandu and welded to completion in a local shop. Everything else was clamped together with scaffolding. The parts of the structure that had to be geometrically accurate were done with 1.5″ metal piping, and all other supports were local bamboo cut from Maya Universe Academy’s land. The first row we installed was also welded in a local shop.

Moving forward

Instead of calling this project a failure because I didn't complete it in time, I am counting this time as valuable groundwork towards the project's goal. Meanwhile, the steam engine has reached Kathmandu, the boiler is manufactured and all the contacts have been made for the supplies of mirrors, tools and materials. These are ideal conditions to follow up the project and complete it in a short time.

Budget

This section is split into three parts: (1) the project budget that shows the running expenses of this project, (2) the expected total cost for the solar concentrator, and (3) a cost comparison between the solar concentrator and solar photovoltaic systems.

Project Budget

My initial budget showed that I needed $4100 to build either the micro-hydro or solar fire pathway. With the $5683 that I raised through the campaign, I decided to implement three pathways instead of only one. This is the breakdown of the total money spent.

Table 3: **Running Costs of the OpenPower Nepal Project**

	Appliance/Material	Cost Planned [USD]	Cost Planned [NPR]	Cost Actual[USD]	Cost Actual [NPR]
Pathway I	**Solar Photovoltaic Tracker**				
	Solar PV Panels Mono-Crystalline (2x75 Watts)	0	0	351	30,000
	Tracker and Mounting Structure	0	0	410	35,000
	Charge Controller (24V, 20A)	0	0	53	4,500
	Battery Bank (2x105Ah Deep cycle tubular LA)	1,500	127,965	281	24,000
	Solar UV resistive Cable	0	0	23	2,000
	Inverter (Sukam 1.4kW, 12-24V)	300	25,593	140	12,000
	WLED Lamps (DC Lighting, 5x1.2-5W)	0	0	50	4,250
	Mobile Charger	0	0	15	1,250
	Cables and cabling accessories	0	0	117	10,000
	Subtotal	**1,800**	**153,558**	**1,439**	**123,000**
Pathway II	**Steam Power Plant** from India				
	Steam Engine 3hp (Single Cylinder, Double Acting, Cylinder Diameter 2.5", Stroke 3", complete with hand operated water feed pump, hand lubricating pump for cylinder lubrication, drip lubricator for crosshead lubrication and 16" pulley)	700	59,717	900	76,779

	Appliance/Material	Cost Planned [USD]	Cost Planned [NPR]	Cost Actual[USD]	Cost Actual [NPR]
	Biomass Steam Heater (Water Tube Yarrow Type Boiler Suitable For Biomass Firing With 30 Sq Ft Heating Surface Including Economizer And Superheater, Test Pressure 400psi, Working Pressure 150 Psi Complete With Water Level Gauge Set, Pressure Gauge, Safety Valve, Fire Grates, Spark Absorption Box And 20ft Chimney Set, Interconnecting Pipe Lines, Valves, Pipe Fittings, Etc)	0	0	1,800	153,558
	Electricity Generator (Electromagnetic Alternator Single Phase 220V, X 1 KVA)	300	25,593	300	25,593
	Solar Cookers (1.5 m² solar cooker, 3m² community solar cooker)	0	0	300	25,593
	Transportation (Rajkot, India - Kathmandu, Nepal)	500	42,655	180	15,356
	Import Tax (Customs and VAT)	0	0	696	59,376
	Subtotal	**1,500**	**127,965**	**4,176**	**356,255**
Pathway III	**The Solar Concentrator (Running Costs)**				
	Corner Pieces with Wheels (Contract)	400	34,124	50	4,266
	Metal Pipes for Structure			140	11,943
	Scaffolding (30x)			50	4,266
	Row Contract			40	3,412
	Mirrors	200	17,062	100	8,531
	Mirror Bending Device	100	8,531	300	25,593
	Boiler with Stand	100	8,531	200	17,062
	Subtotal	**800**	**68,248**	**880**	**75,073**
	Total	**4,100**	**349,771**	**6,495**	**554,327**
	Donations	4,100	349,771	5,683	484,817
	Personal Contribution	0	0	812	69,280

My personal contribution was necessary to cover the unforeseen cost of importing the shipment from India into Nepal. For the future, I have made better import contacts that can lower or remove the import tax of 25% that I had to pay.

While the initial plan was to use the steam engine and a generator to charge a battery bank, I found that it makes more sense to use the steam engine to power local industries such as milling directly. There was a mill shed nearby that stopped operating a few years ago, and we decided to power the mill with the solar energy. This reduced the need for a big battery bank, freeing up my budget for implementing the solar PV tracker with a smaller battery bank for domestic use only.

Solar Concentrator Budget

In building the solar concentrator, the main challenge was to find workable materials. As I made the right connections, I ordered small quantities of materials for testing and implementation. I have not yet finished the solar concentrator, but I purchased some quantity of every material needed for its construction. The expected total cost of production in Nepal are in the table below. All predicted costs are in bold.

Table 4: **Solar Concentrator: Expected Cost of Production in Nepal**

	Appliance/Material	Units	Unit Cost [NPR]	Total Cost [NPR]	Total Cost [USD]
Solar Concentrator	The Solar Concentrator P32 (Expected Total Costs)				
	Corner Pieces with Wheels	4	1,200	4,800	56
	Metal Pipes for Structure (19”)	10	980	9,800	115
	Scaffolding	30	50	1,500	18
	Row Contract (Galvanized pipe, trussed)	20	1,700	34,000	399
	Mirrors (Aluminum, 4mm Plastic Backend) [m^2]	32	700	22,400	263
	Mirror Bending Device (Box-tubing) [m]	32	50	1,600	19
	Nuts and Bolts (Bending device)	1	3,000	3,000	35
	Boiler with Stand	1	17,000	17,000	199
	Steam Piping [m]	15	300	4,500	53
	Subtotal	145	24,980	98,600	1,156
Potential Side Costs	Steam Grid Basics for P32 (Expected Total Costs)				
	Leveling Ground & Concrete Circular Track	1	30,000	30,000	352

Appliance/Material	Units	Unit Cost [NPR]	Total Cost [NPR]	Total Cost [USD]
Steam Engine (TinyTech, 3hp)	1	60,000	60,000	703
Pump (Hand Operated)	1	30,000	30,000	352

Price and Efficiency Comparison with Solar PV Panels

The current solar concentrator comes to a total cost of just above a thousand dollars. The peak output of the 32m^2 system is 15kW in thermal heat. Transferring this heat into motion through a steam engine at 20% efficiency would end up with a total output in motion of 2.4kW. Due to thermal losses (<20%) along the way and 10% loss at the conversion from mechanical power to electricity by means of a generator, the total electricity output of such a system should be around 2kW of electrical current.

To produce electricity, we have to add a steam engine and a generator to the cost of the solar concentrator, resulting in a total cost of $2023.

Table 5: **Solar Concentrator for Electricity: Cost of Production**

Electricity-Producing Solar Concentrator Parts	Total Cost [NPR]	Total Cost [USD]
Solar Concentrator 32m^2	30,000	1,156
Steam Engine (TinyTech, 3hp)	60,000	703
Generator (2kW)	14,000	164
Subtotal	**104,000**	**2,023**

That translated into a per kilowatt cost of $1012.

Table 6: **Per Kilowatt Electricity: Cost Comparison**

Electricity Producing Appliances Per Kilo Watt (kW) Cost	Total Cost [NPR]	Total Cost [USD]
Electricity Generating Solar Concentrator 32m^2	52,000	1,012
Electricity Generating Solar Photovoltaic Panel, Installed	120,000	1,407

In terms of renewable energy, this is a competitive price to solar PV panels that currently sell between $1000 to $2000 per Kilowatt. Both solar PV and solar concentrator systems can be expected to become more efficient and cheaper in the future, but notably, solar concentration is already at a competitive price.

Table 7: **Per Kilowatt Heat: Cost Comparison**

Electricity Producing Appliances Producing 15kW of Heat	Total Cost [NPR]	Total Cost [USD]
Heat Generating Solar Concentrator 32m^2	52,000	1,012
Heat Generating Solar Photovoltaic Panel, Installed	1,800,000	21,100

Discussion of Cost Comparisons

I used conservative numbers in my model above to reflect the performance and cost of the TinyTech steam engine. The model steam engine was only 20% efficient, but steam engines can perform up to 40% efficient[11]. Thermal losses could be reduced from 20% with better insulation, perhaps to 10%. This would make the overall efficiency higher.

Apart from the electricity output, the solar-steam based solution also creates so called waste heat coming from the exhaust of the steam engine. The waste heat, a mixture of steam and water, can be up to 150°C. This temperature can power small-scale industrial processes such as baking, roasting, dying, distilling, sterilization, pasteurization, etc. If a solar concentrator is built for heat applications directly (this yields steam at 300°C), or if the waste heat is put to use, then the solar concentrator yields immense benefits over current renewable energy alternatives.

Heat through electricity is a very inefficient approach. Electricity for electronics, however, is very efficient. A laptop can consume up to 0.1kW. A heating plate on an electric stove easily consumes 1.5kW. It therefore makes sense to use electricity for lighting and electronics, but not for thermal needs. To create 15kW in heat, one would need $21,100 in solar PV panels (electrical), or $1012 for a solar concentrator (thermal). Clearly it is more cost-efficient to use solar concentration, to grow and burn trees, or to use biogas — instead of using solar PV panels — to create heat.

11 "Steam Engine." Wikipedia. Wikimedia Foundation, 22 May 2012. Web. 24 May 2012. <http://en.wikipedia.org/wiki/Steam_engine>.

Plans

Design Rationale

During my visit to TinyTech I helped construct a $90m^2$ concentrator. This machine including a 10hp steam engine currently costs $10,000. For a system that produces 7kW of electricity, this is still competitive with solar photovoltaic systems. Assuming a market price of $1.5 per Watt for photovoltaic cells, an equivalent array of solar panels would cost $10,500. Besides the electricity, the steam-based solar concentrator system also yields waste heat that can be used for pasteurizing, drying, baking, distilling, and disinfecting, putting this technology at a clear advantage if the waste heat can be utilized.

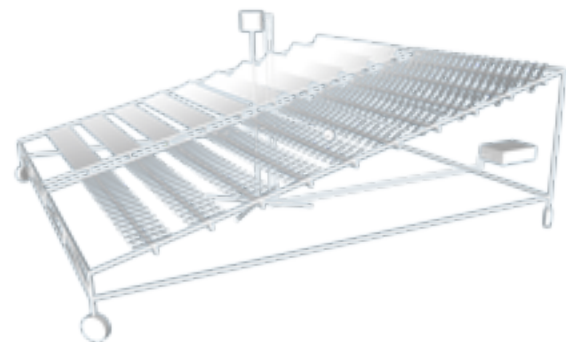


Diagram 3: A rendering of the solar concentrator on wheels.

My plan for Nepal was to cut costs further, for example through using local materials such as bamboo, and by simplifying the structure so it could be built with less material.

During my visit at TinyTech I contemplated the heavy central mast that holds the whole structure upright. The reason to have a central mast was so that the structure could be turned with minimal friction. With the mast, the boiler would be fixed, but everything else would turn around it. The water input and steam output pipes travelled down the mast until they came to the pivot point, at which they had to come up with a special mechanism to allow for the static pipes to bypass the pivot point.

Once I tried to lift the central mast pivot piece from one end. It was less than two meters long, but I could not lift it. Heavy materials are expensive and difficult to transport, so I decided to come up with a new design that would not use the central mast.

The solar concentrator must be able to move freely in two degrees. (1) The whole structure needs to follow the movement of the sun from east to west, and (2) the individual rows with the mirrors need to be adjustable for the height of the sun. By leaving out the central mast, I had to come up with my own approach to make the structure follow the east-west movement of the sun.

Heavy-duty central mast with pivot point.

Solar Concentrator P32 on Wheels

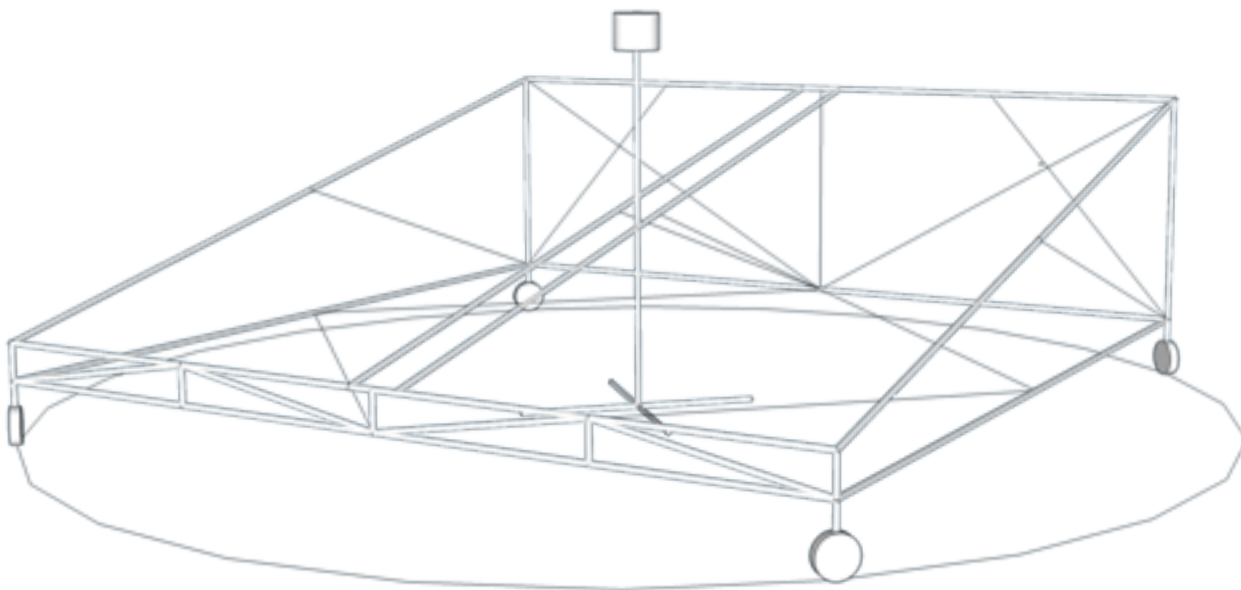


Diagram 4: Rendering showing the solar concentrator frame on wheels. The thin black lines indicate the use of bamboo.

Based on the solar concentrator P32[12] I created a solution with wheels. There would have to be a perfectly leveled floor and a free standing mast at the center. In this structure, the weight of the mirrors could be brought down to the earth at the four corner points at which

[12] Solar Concentrator P32 by Eerik Wissenz of SolarFire.org, 2011, http://solarfire.org/Solar-Fire-P32-Description

wheels would be mounted. This would reduce the structural complexity and material costs.

The next design-obstacle were the steam pipes. There are no flexible pipes available to work at the high pressures and temperatures of steam. Therefore, the pipes need to be fixed relative to the boiler and the steam engine while the concentrator structure needs to revolve around it. If the boiler instead were attached to the structure on wheels, the steam engine would have to be mounted on the structure as well. That again would increase the weight which would require more structural stability.

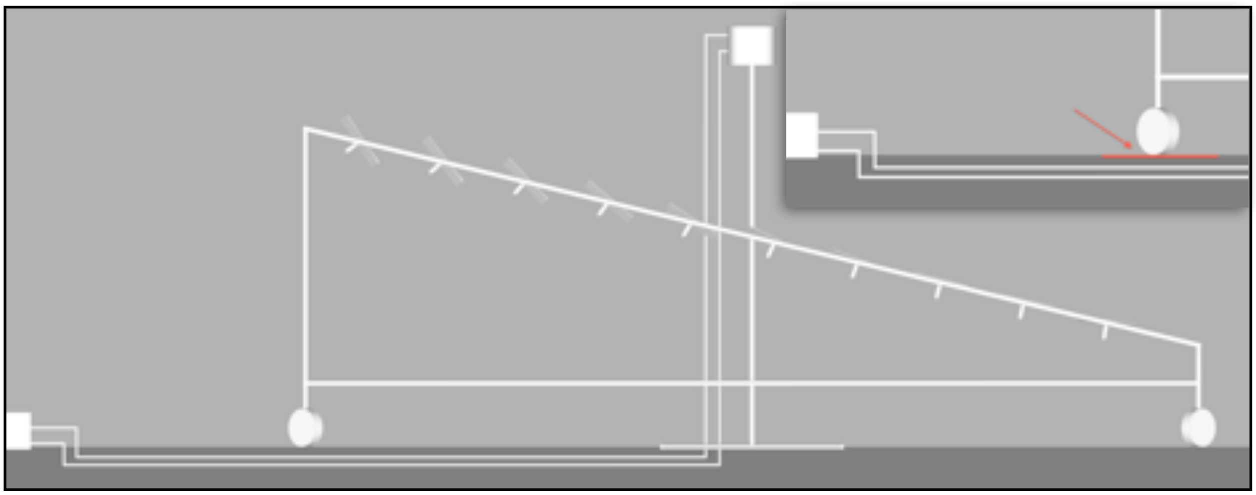
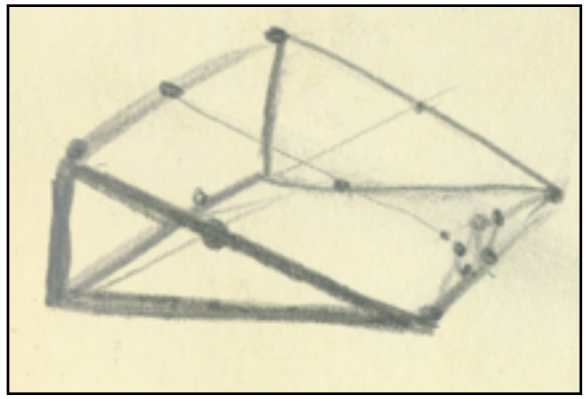


Diagram 5: The solar concentrator in elevation. (Big) the flow of the steam and water pipes between the boiler and steam-engine. (Small) at some point, the pipes need to underpass the circular track. The tunnel for the pipes needs to be covered by a metal plate (red line).

On the other hand, with a free standing boiler, the central mast has only one function: to keep the boiler elevated. The pipes running down the boiler could either run out of the boiler above the structure, or travel down the mast. If they travel down the mast, it would get underneath the structure and would have to underpass the circular track upon which the concentrator turns. I decided to go with this model. It required digging an underpass below the circular track through which the steam pipes would travel. A metal plate would bridge the underpass for the wheels of the solar concentrator. The above diagram shows the steam pipes running in a trench below ground level.

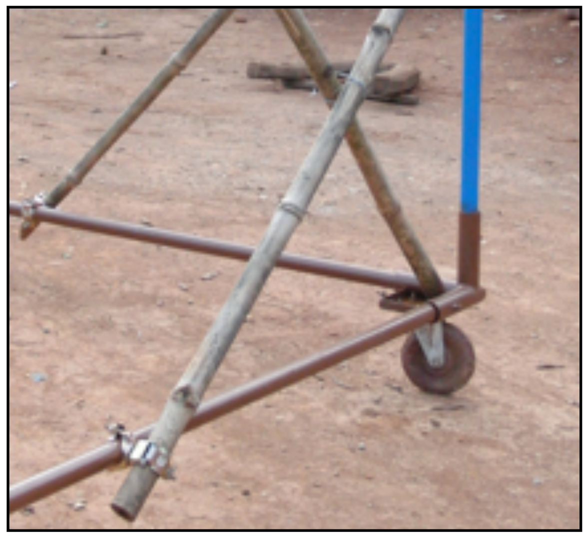
Concentrator Structure and Corner Pieces

The rest of the structure was fairly straightforward. For geometric accuracy I decided to use 1.5” (inch) metal pipes (⅛” gage) for those parts of the structure that had to be congruent. Together with a local welder, we manufactured corner pieces with exit pipes of a 2” diameter, so the smaller diameter structural pipes would slide into the corner pieces and could be fine-tuned in their length with a fixing bolt.



A sketch of the solar concentrator frame.

For giving the structure rigidity, bamboo was cheaply available at a local level. I bought scaffolding that was available in Kathmandu, for less than 1.5 USD per piece. This allowed bamboo and metal to be connected without drilling holes, retaining their structural strength. In the diagrams, the fine black lines represent bamboos with scaffolding attached to the structure for rigidity. The white lines represent the 1.5 inch metal piping.



Bamboo and metal pipes were interconnected with scaffolding.

The corner pieces and scaffolding joints have been left out of the renderings for simplicity's sake but can be seen in the picture on the left. The corner pieces were welded while I was scouting for materials in Kathmandu. The initial corner design had some uncommon angles (18° and 72°) but Govardhan simplified the corner pieces to only have 90° angles. This makes contracting the welding easier. Then we fixed the row-support pipes with scaffolding.

A corner piece with a wheel. For simplicity, the top pipe that comes down at an angle bypassing the corner piece.

The scaffolding allowed for dynamic readjustments on the structure as it developed. The side-pipes to which the rows are attached (blue pipe in image above) meets the corner at an odd angle, but since we used scaffolding, attaching the pipe was straight-forward.

Structural Improvements

During the construction I found an error in my initial design that I corrected in this model. In my build the front pipe was a simple pipe. All other pipes and points are properly gravitated, meaning the weight they carry was brought down to a corner piece. However, the middle of the front pipe does not have any support and therefore will bend under weight. Bending is not a problem as long as the structure remains symmetric, but I suspected the bend would cause the pipe to touch the ground. To avoid this, I designed a box truss for the front pipe. Bamboo and pipes are strong when used as a columns, but they bend (and eventually break) when the same force is applied from the side. Trussing pushes all stresses onto columns, thus increasing structural strength. With the bamboo trussing in place, I was able to hang off any of the top pipes in the structure with no significant bending.

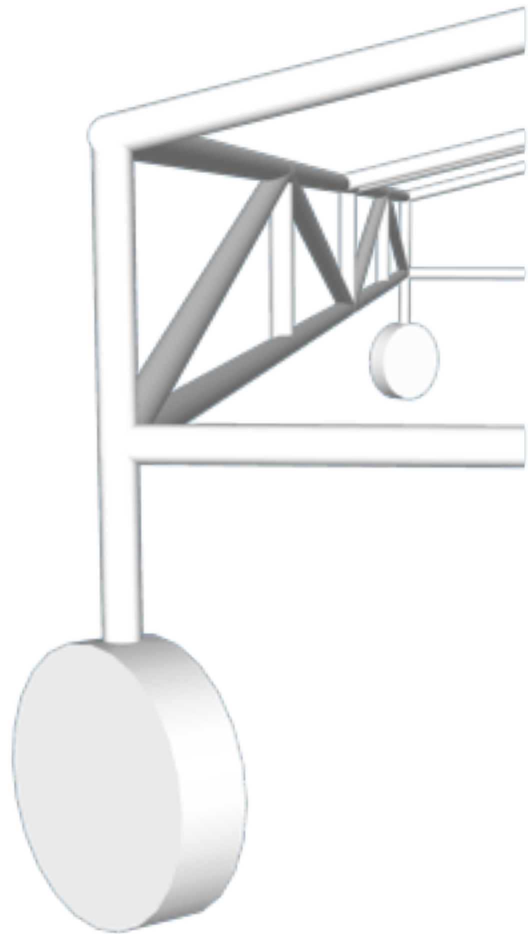


Diagram 6: A rendering of the front pipe of the structure that has to be supported with a box truss to avoid bending under weight.

Mirrors

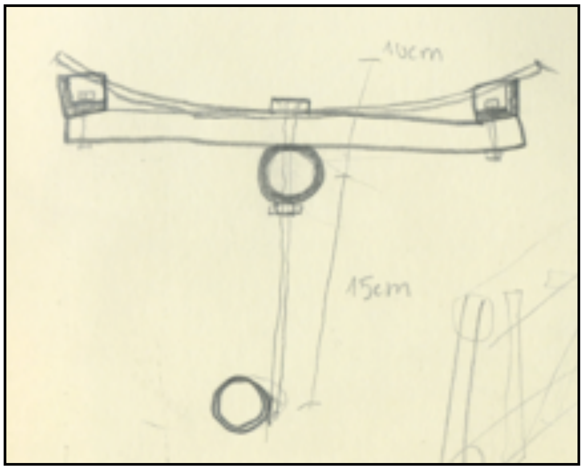
Apart from the structure, the individual mirrors are key to the function of a solar concentrator. Each mirror of 8" by 24" needs to be bent ever so slightly to bring the sun-rays together into a smaller area. That area will be the width of the mirrors, which will be aimed at the boiler.[13] The boiler should have a surface area double the width of the mirrors to catch the rays even if the system is not perfectly calibrated. The mirror material I used was so flimsy that it had to be handled with great care. It was a 0.5mm aluminum type mirror sheath, coming in 48"x48" sheaths. To make it more rigid I attached 8mm plywood to the back using synthetic resin adhesive glue and covered the plywood with protective shellack. The optimal material to use is a 4mm plastic sheath, but that was not readily available in Kathmandu. I found that readymade aluminum mirrors with various thicknesses of plastic backends can be ordered from China. Prices can be as low as $2/m^2$.

The mirror material allowed for drilling. Threaded rod with a set of nuts and washers allowed the mirror and bending device to be fixed.

Instead of using expensive epoxy resin to glue the metal rod to the back of heavy glass mirrors as done at TinyTech, the mirror material I used allowed me to drill a hole through the font and attach the threaded rod using nuts and washers.

[13] There is a video on the OpenPower Nepal blog explaining the bending device and the resulting solar concentration. <http://www.mayauniverseacademy.org/day-90-project-updates-2>

Bending Device



Mirror with bending device attached to row (Section).

Note: The mirror rod is attached with resin and the bending device is a complex metal shape (red).

At TinyTech, they used a complex bending device with many parts. I simplified the device, which proved to be very practical and cheaper to manufacture. As compared to the TinyTech bending device, my design does not space the rod coming out from the mirror as far out, which means it can be attached closer to the row, making it easier for it to stay fixed in wind and weather. I used ¾" angle iron as it was available in Damauli, the town closest to MUA, but using aluminum or iron box tubing is a better choice as very thin gauges can work that would reduce the total weight of the bending device below a pound.

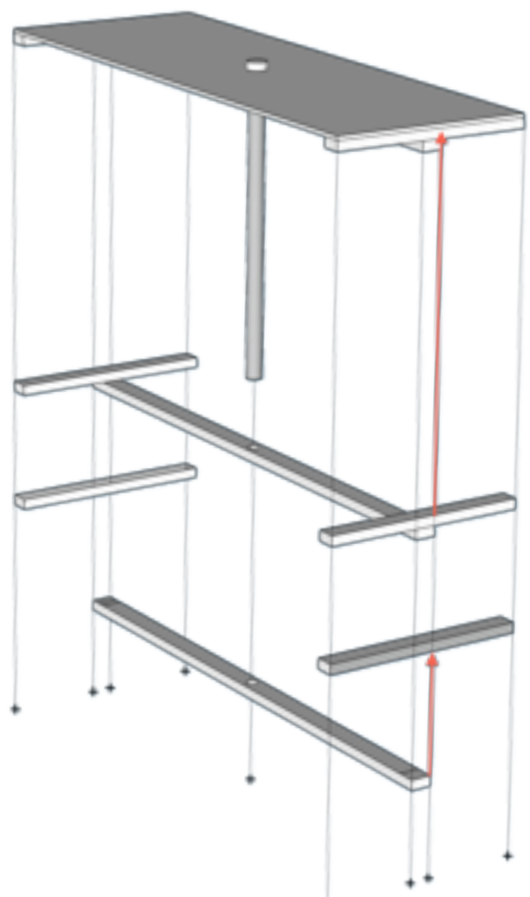


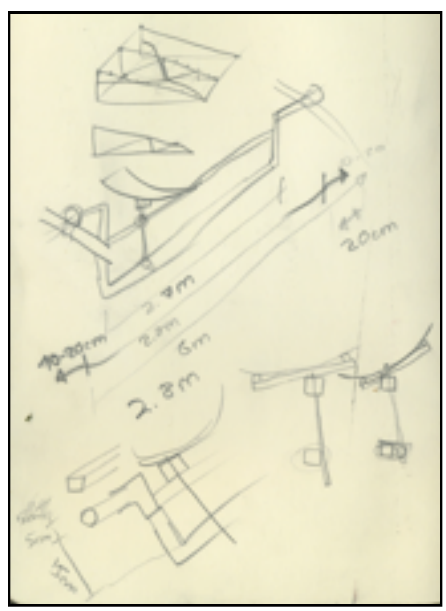
Diagram 7: A rendering of the simplified bending device.

The following drawings illustrate the bending device which can be adjusted on the rod of the mirror to exercise pressure to the short ends of the mirror, resulting in a bend. The more rigid the backing of the mirror is, the more equal the bend will be. Plywood of 8mm thickness worked in combination with the 0.5mm aluminum sheath available from local suppliers.

Rows

The row was made out of ½” galvanized pipe, trussed with iron plates. Scaffoldings were used as twist-mounts.

Although SolarFire.org had developed the more rigid triangle-truss method, we decided to use the row design used at TinyTech, because it was simpler to weld because there were only 90° angles in it. The welding was done in nearby Damauli and loaded on top of the public bus that runs between Damauli and Thanahunsur, the top of the district, once a day. It would take the shop about three hours to weld a row.



Sketching out ideas for the row-design.

Boiler and Stand

While sourcing the mirrors I worked together with the engineer and business owner Niraj Shreesta of *SunWorks Nepal*. The renewable energy scene in Nepal is very connected. I got redirected to Niraj on my quest for materials and parts many times. In Muni's words Niraj was the one man of Kathmandu who knows how to make custom gears, the same gears that run the solar trackers Muni builds. Niraj builds solar hot water heaters and has experience with biomass air heaters. Because of his experience with steam and pressure appliances, he was the go to man for manufacturing the boiler. He calculated the wall thickness to be 6mm to accommodate for the 150psi working pressure. The welds have to be very thorough because of the temperature swings that the boiler is exposed to during refill. Cold water entering the boiler will shrink the metal in some areas, creating so called heat-stress. Bad welding could potentially lead to explosion. Fortunately, Niraj has skilled welders in his shop.

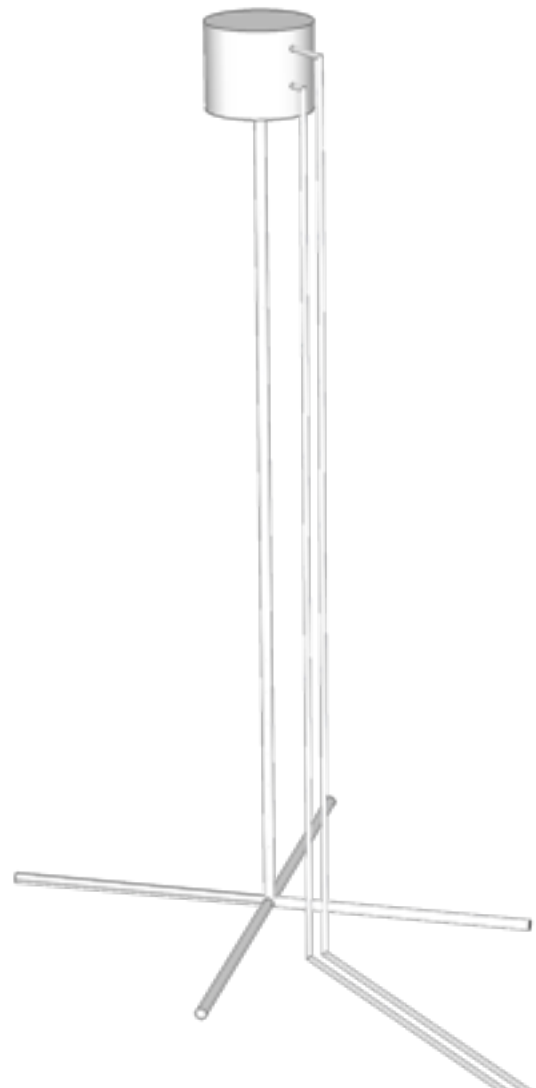


Diagram 8: A rendering with the pipes following the stand and entering and leaving the boiler.

On the boiler I consulted heavily with Eerik Wissenz of SolarFire.org and worked out the details with Niraj. The boiler sides should be of cylindrical shape. To minimize welding joints, we seized the boiler down from a 40cm diameter to a 38cm diameter so that the sides could be made out of one piece of steel. The top and bottom need to be convex/ concave to be able to deal with the pressures. The water entry point is going to cause the greatest thermal stress, and we positioned it into the lower half of the boiler, the steam outlet in the upper half. The whole boiler will be mounted on a perforated 1.5" pipe that will slide down the boiler stand with its 2” pipe. This pipe has a bolt for fixing the boiler at a specific height through one of the perforations. This kind of welding job can be done within a week at Niraj’s shop.

Solar Tracking

Muni Raj has developed a simple way to track the sun. As opposed to a high-tech approach with a microchip programmed for certain coordinates and sending signals to adjust motors depending on the daytime, he uses a simple, analog feedback mechanism. This feedback mechanism could be used to allow solar tracking even in the solar concentrator.

Muni’s simple solar tacking mechanism using two 5 Watt panels.

The system uses two small 5 Watt solar panels and a DC motor, all connected in a loop. Both panels are facing the sun at an angle as shown in the picture to the right. When the array is perpendicular to the sun, both panels are getting the same amount of sunlight and produce the same output. Because they are in a loop, the equal charges prevent a current from forming.

As the sun moves, the angle between the sun and the tracking device will change and one panel will start to get more sunlight, therefore producing a stronger output than the other panel, resulting in a current flowing along the loop.

The current moving through the system will then spin the DC motor. This mechanical output can be used to adjust the whole structure. Because the strength of the motor is low, Muni used a transmission to turn his solar trackers. Two such tracking devices need to be installed: one to track the east-west movement of the sun, and another for tracking the up-down movement of the sun.

Discussion

While writing this project report and looking over the past half year, I realized that this was a big learning experience for me.

I learned to be more skeptical of the people I trust. I learned this after I repeatedly confirmed a shipping duration with my Indian contact. He informed me to the best of his knowledge, in an honest way, but I still should not have taken his definite statements as truth. When it came to importing the shipment to Nepal, I was also told from both sides not to worry about the border: that there would be no problem. I do not worry naturally, so when I'm told to not worry, I don't. Later, I started to worry. The import tax came to a significant sum that could have been avoided was I told to prepare. This made me learn things the hard way. With such lessons, I am now more prepared to question and be skeptical of my sources.

I spent 143 days fundraising, and less than half of that time building in Nepal. It is a lot of work to raise money and it would be more efficient to spend less time spreading the word and more time developing new innovations. Thirty days for the project writeup also seemed short, but I hope to have done justice to the account of what happened. I hope this account provides a foundation for further development.

With an additional month in Nepal, I would have been able to implement pathway II and finish pathway III. However, because of my graduation and because this was my last chance to use COA's travel grants and facilities, I had to do this project with a constricted timeline that conforms with COA's calendar.

I was very exited installing the first mirror on the solar concentrator. The mirror proved that my plans and ideas worked. I had developed a solar concentrator on wheels and a simplified bending device. I was proud of these accomplishments because simplification is key in making technology appropriate and usable, and often lowers its cost. I am curious to see if these developments will find their way into the plans of other solar concentrators.

Conclusion

With this project I wanted to see what is possible. I aimed for a big accomplishment, and along the way, I learned a ton. The OpenPower Nepal project is not yet finished, but the little success I made in Nepal is a big motivation for me to continue this work.

Less than a year ago I decided to embark on this journey. I had little idea what lay before me, and I didn't know how far I could get. With this project, I made a great start, but I realize that there is still a lot of work to be done to enable cheap, local, and open source access to renewable energies in this world.

I hope this project inspires others to follow my steps and keep moving: set a goal, and start working it out. You might get quite far. People take you seriously if you work for a sound cause. The respect, support and hope people put into me answered my most fundamental question: The way in which I wanted to accomplish change was resonating with others, and they were ready to step out of their way to help me succeed.

If you have any questions, plans and ideas, don't hesitate to contact me at:
urs.riggenbach@solarfire.org.

Future

On my way back to COA, Eerik Wissenz invited me to join the board of the SolarFire.org organization. Their plan is to foster open source and solar fire technology throughout the world by supporting those who want to adopt and adapt it.

As part of the organization, I again started to raise money to hold a developer summit at my farm in Switzerland during summer 2012. This time I want to focus exclusively on the solar concentrator, and document it further so that it can become easier for others to follow our footsteps.

Eventually, we hope to provide guidance to others through workshops and on-site consultation. Many of my COA and UWC friends are starting farms and/or are trying to grow their local economies. Already I have been invited to help construct solar fire technology on farms in the Caribbean, Africa, and Latin America.

Within the next year I am planning to return to Nepal and finish implementing the missing pathways. Demonstrating a working technology in rural Nepal should grab the attention of many NGOs and help us spread this simple technique for renewable energy access further.

For now, we need all the support we can get for the build at my farm this summer. Check out the campaign and stay up to date with the solar fire revolution at www.SolarFire.org.

This is the last slide of my senior project presentation that I gave to COA's trustees. Now that I am working on another fundraising campaign, I have come full circle.

Appendix

Acknowledgments

These are some of the people who provided me with inspiration and valuable resources for this project:

- Molly Anderson and Davis Taylor of COA were my project advisors.
- Eva and Eerik Wissenz of SolarFire.org provided me knowledge and support for applying the solar fire method to Nepal.
- The Open Source Ecology project and the European Network thereof inspired my work in the field of open hardware and keep me up to date with similar efforts around the world.
- V K Desai of TinyTech India provided me with the steam engine, biomass heater and hands-on experience on building a solar concentrator during my visit in India.
- Jon Archer of the Zocalo Permaculture Center in Maine taught me about the battery bank design, assembly, and maintenance.
- Ino Fleischmann of GlobalAnchor.org provided specifications of his micro-hydro system.

Thank You, to:

- Manjil and Govardhan Rana, for inviting me into their family, showing me Nepal, and sharing a great time.
- Anmol Basnet, Sam Joachim, Rikke van der Veen, Surya Karki, Rahul Malla, Asish Adhikari, Ashankan Malla, Luise Duhan, Fanny Herr'uai, Joseph Layden, Dan Bandur, Suvas Rana, Julian Tsapir, and many volunteers at the Maya Universe Academy not listed.
- Muni Raj and Niraj Shreesta, for their technical support on construction and materials.
- Sagar Paudel for helping me out on the import front.

- Burt Wartell, a machinist from Portland, ME, USA, for informing about steam engines, their inner workings, and their operation.
- The Davis Foundation and College of the Atlantic for my scholarship to COA.
- The Kathryn Davis International Advanced Studies Award for a travel grant.
- The Fund for Global and Civic Engagement for a travel grant.
- Donna Gold for releasing a press release about my project.
- The Yestermorrow Design/Build Semester teachers and class of 2011, especially Terri Chapman and Harry Harris.
- Martin and Ursula Riggenbach, my parents, for supporting my path.
- Christian Riggenbach, my brother, for supporting the cause with his visit and donation.
- And many people along the way for showing interest, supporting the cause, and giving advice.
- All donors are listed below.

List of Donors

2012/03/19 9:05 PM
Arnoud van der Sman made a donation

2012/03/16 7:06 AM
Christian Riggenbach made a donation

2012/02/08 3:51 PM
Sam Robey made a donation

2012/01/26 2:32 PM
Anne Aviles made a donation

2012/01/25 5:09 AM
David Stickelberger made a donation

2012/01/17 9:12 PM
Herbert Kyburz made a donation

2012/01/08 2:22 PM
Ronald Beard made a donation

2012/01/07 7:23 PM
Claude Henry made a donation

2012/01/02 5:31 AM
Branislav Misovic made a donation

2011/12/29 6:46 PM
Anna Cantavenera made a donation

2011/12/28 4:26 PM
Eerik Wissenz of SiSustainable made a donation

2011/12/25 6:03 PM
Marlon Plein made a donation

2011/12/21 7:07 PM
Donna Gold made a donation

2011/12/21 3:40 PM
College of the Atlantic made a donation

2011/12/14 4:10 PM
Matthew Sutter made a donation

2011/12/12 10:14 PM
Catherine Clinger made a donation

2011/12/09 6:17 PM
Britton Evans made a donation

2011/12/03 5:34 PM
Flora Wong made a donation

2011/12/03 3:15 AM
Angelika Adensamer made a donation

2011/11/29 1:35 PM
Molly Anderson made a donation

2011/11/24 3:06 PM
Carey Clouse made a donation

2011/11/21 5:33 PM
Kylee Gies made a donation

2011/11/21 2:09 PM
Jose Galarza made a donation

2011/11/20 8:32 PM
Jacob Hoffman made a donation

2011/11/19 11:31 PM
Nikolay Georgiev made a donation

2011/11/16 6:53 AM
Linis Dolby made a donation

2011/11/08 2:43 AM
Sunny Baral made a donation

List of Open Source Software Used

Planner

http://live.gnome.org/Planner

Planner is a simple software for GANNT diagrams and allows exports in PDF and SVG.

List of Open Source Software Used

Labyrinth

http://code.google.com/p/labyrinth/

Labyrinth is a simple tool for mind-mapping and allows exports in PDF and SVG.

Inkscape

http://inkscape.org/

Inkscape is a tool for vector based graphic designing based on SVG. It has simple functionalities and therefore is a good way to get started with computer graphic design. All diagrams have been made or colored up with Inkscape.

OpenSCAD

http://www.openscad.org/

OpenScad is a software for 3D modeling and rendering. I used it in combination with Google SketchUp, and Blender.

Wordpress

http://wordpress.org/

Wordpress is a professional blogging software and has enabled thousands of people to have a voice in the blog sphere.

Donation Can

http://treehouseapps.com/donation-can/

The Donation Can plugin integrates with Wordpress and PayPal. It allows for dynamic fundraising towards a set goal and can be configured into a standalone fundraising widget.

OpenSCAD

http://www.openscad.org/

Is a 3D modeling software. I used it in conjunction with Google SketchUp.

Linux

http://en.wikipedia.org/wiki/Linux

All the above software runs on Linux; some of them will not run on any other operating system. I like Linux because it is secure, fast and has a system wide software management. There are many types of Linux for different purposes. Ubuntu and Arch Linux are my favorites.