LIGHTING UP THE Nepalese villages

A
PROJECT PROPOSAL
SUBMITTED TO

MONDIALOGO

BY:
NEPAL/US MONDIALOGO TEAM
(Team UJYALO)

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Nepal	**USA**
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Sustainable Technology - Adaptive Research and Implementation Center, Nepal	

"LIGHTING UP
THE
NEPALESE VILLAGES"

PROPOSED COUNTRY OF IMPLEMENTATION

KINGDOM OF NEPAL

Project Advisor

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Professor
Research Director
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ABSTRACT

This proposal, jointly prepared by the teams from Nepal and USA, intends to propose solutions for improving rural kitchen environment in developing countries. It describes the technologies explored and developed by the teams to produce white light for illuminating kitchen by using improved cook stoves. It explains the evolution of the project idea, and the contribution of team members in developing the technologies. It assesses the secondary impacts of the developed technologies on reduction of indoor air pollution in rural households' kitchens and in improving the kitchen environment by helping to effectively disseminate improved cook stoves. The proposal also highlights the development of mutual cooperation and friendship between the two teams in order to address the issue.

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I. INTRODUCTION

A. PROJECT IDEA

Almost half of the world's population uses biomass for cooking and heating. In Nepal, approximately eighty percent of the people use biomass. This enormous usage of solid fuels has a dramatic effect on air pollution, indoor air quality, health, and deforestation.

The use of primitive cook stoves can fill houses and huts with levels of hazardous air pollutants (HAPs) that are far beyond safe levels. Stoves release high levels of formaldehyde, carbon monoxide, NOx, and other harmful chemicals. This has a devastating effect on the health of users, leading to reduced life expectancy and increased child mortality.

Stoves also have a detrimental effect on the land. The use of inefficient cook stoves is leading to massive deforestation in many parts of the world. Worldwide, billions of dollars are spent each year in attempts to reforest hillsides, but this has typically been a losing battle. A more cost effective and sustainable solution is needed to prevent this deforestation.

One of the priorities for United Nations Millennium Development Goal is providing clean energy for households in developing communities. Access to clean energy is an indication of increasing prosperity. Currently, the privilege of having clean energy in Nepal is limited only to the urban areas. Most of the people of Nepal are forced to be satisfied using firewood as fuel. Not surprisingly, fuel wood constitutes about 74% of the total energy demand, thus putting a huge pressure on the forests of Nepal. Of the 23 million people of Nepal, more than 19 million use cookstoves. Non-Government Organizations (NGOs) and International Non Government Organizations (INGOs) in Nepal are committed to reducing greenhouse gas emissions and Acute Respiratory Infection (ARI) caused by wood burning, but this has been difficult. To reduce these health and environmental effects, promotion of improved cook stoves by the government has been accelerated. However, there are still burning issues that need to be addressed to make the implementation of clean stoves successful.

One reason why clean stoves have not been successful is that they commonly require more effort and attention from the user. Another is that they require changes in cooking habits and culture in general. Many people resist this change. Clean stoves also eliminate the light produced by the traditional open fire. Without this light clean stove users must sit in complete darkness during the evening hours. This problem could be addressed by generating a small amount light directly from the stove.

There could also be additional benefits to generating light. The availability of quality, white light can enable people to be more active in the evening hours. If people have the opportunity to read at night, they have the ability to educate themselves. In this way, the availability of a quality light source could potentially reduce poverty in developing countries and ensure universal primary education.

The generation of light could solve one of the largest problems in the dissemination of clean cook stoves today. Not only will the proposed technologies replace the light lost from traditional fires, but also the light will be much higher quality than before. We believe this capability to generate light will be so highly valued by the user that they will be more willing to make any cooking or cultural changes to have this commodity.

B. MANAGEMENT SUMMARY

Keeping in mind the numerous issues that haunt a developing country like Nepal, frequent in house meetings were organized by both the teams in their respective countries. The proposal submitted earlier in April was focused on coming up with a technology to reduce indoor air pollution, which meant designing an improved cook stove or designing biogas systems. Frequent late night meetings were held between CSU team members. Because CSU team had a member from Nepal, it was easier for the CSU team to understand the situation in Nepal. Many arguments for and against developing improved cook stoves or designing biogas systems were put forth. But with much more discussions within the CSU team and with the Nepalese team through telephone calls and emails, it was realized that the teams should approach the issue of reducing indoor air pollution by alternatively addressing the hidden problems in effective dissemination of cook stoves. The problem of loss of light due to introduction of improved cook stoves was identified as the major barrier to the dissemination of cook stoves. It surmounted all other problems and the two teams decided to work on it.

The combined 9 member team of CSU and TU team was divided into groups. Dan Mastbergen and Sushim Man Amatya worked on the thermoelectric generator. Roberto Arranz, Civil Engineering Student from Spain was responsible for coordinating meetings, updating EWB/CSU forum, Google searching on various relevant technologies and motivating both teams to work towards the goal. He was paired up with Bishnu Acharya from Nepal. Ryan lee and Pawan were paired up to work on hand cranking device. Kiran Gautam, Sachin Joshi and Rajeev Man Shrestha worked on producing light from Biomass. Since, Rajeev Man Shrestha and Sushim Man Amatya were also working as research officers on improved cookstoves in the Nepalese NGO (Sustainable Technology Adaptive Research and Implementation Center/Nepal), it was easier to obtain information regarding the status of improved cook stoves and their dissemination in Nepal.

CSU team was engaged more into fabricating and testing the technologies in the laboratory while the Nepalese team was primarily involved in providing feedbacks and suggestions so that the technology could be suitably adapted in the rural households of Nepal.

CSU team members had a chance to take part in summer stoves camp in APROVECHO Research Center in the USA where the issue of producing white light via cookstove was explored. Dr. Bryan Willson, Project Advisor, Dan and Sachin fabricated and tested a gasifier cook stove to produce light as well as for cooking. The encouraging results were shared between the CSU and Nepal team and its immense application was soon realized.

II. INTERCULTURAL DIALOGUE

Once the problem statement was fixed, we started working towards a possible solution. Intercultural dialogues were done via Internet, using email, e-phone, msn chat as well as phone. The exchange of emails between the two parties is included in the Appendix. Since the team members were paired up it became easy to work. However, it didn't always work out when someone would have to go back home where no communication was available. Besides proposing feasible solutions, the members were encouraged to know each other on a personal level, exchanging information on each other's cultures and developing a long lasting friendship. MSN messenger service, EWB – CSU forum (www.engr.colostate.edu/ewb), and normal emails were used for that purpose.

Exchange of information has been continuing since August 2004. Since then, the dialogue has not stopped till date.

The group from Nepal was involved in research and implementation of cook stoves in rural Nepal. During the research phase, the researchers had already faced the problem of lighting. Once the old stove was to be replaced by the new one, there would be no light in the room. No tradeoffs were possible with the efficiency of the stove. We had to find an alternative solution for lighting. It was then, when lighting via cook stove became the focus of the Mondialogo Project.

We hope to continue our intercultural dialogues to build a good network. Since the proposed solutions are feasible technically and economically, we hope to implement these ideas in the field so that we can help the poor people of Nepal. This would require the CSU team to travel to Nepal and get first hand experience of living and working in a developing country. This would help to create a stronger bond of friendship between the two teams here at CSU and Nepal. We believe that being in contact with each other would help us understand and learn to appreciate each other's cultures and work towards a common goal – to help the poor people in need.

III. PROPOSED SOLUTIONS

After discussing several technologies between the two teams, the following three were identified as feasible solutions.

a. Thermal Lighting from biomass cookstoves using Welsbach Mantle
b. Integrated thermo electric generator onto the cook stove
c. Hand Cranking device for lighting.

The first two technologies make use of the biomass cook stoves, which can be found in almost all the local households. The last technology is being currently used by companies to produce small hand held flashlights and radios.

a) Thermal Lighting from biomass

Poor people in Mountainous regions use wood resins or kerosene for producing light. This method is based on an incomplete combustion principle. The yellow flame produces soot, CO and CO2. In a confined space of rural households, the use of such lanterns can be injurious to health. The quality of light obtained from these devices is very low.

A modification of this primitive technology, is converting a cookstove into a gasifier. In this modified cookstove, the heat released in the combustion chamber of the cookstove is used to pyrolyze the wood chips kept around the combustion chamber. This produces a stream of combustible gases, which is lit inside a Welsbach Mantle producing white light. This technology converts a simple cookstove into a stove/gasifier, which can be used to cook food while simultaneously produce white light to illuminate the kitchen. The remaining charcoal in the gasification compartment can be used again for cooking purpose. The preliminary tests were conducted on a rocket metal cookstove in APROVECHO, USA and in the Engines and Energy Conversion Laboratory, Colorado State University. The results so far have been encouraging.

Construction and Operation:

The metal cook stove has an elbow type combustion chamber, which ensures an efficient burning of wood. The interior of the stove between the elbow combustion chamber and the surrounding wall is filled with sawdust and wood chips. As the stove is fired, the heat from the combustion chamber is transferred to the surrounding woodchips and the sawdust. Within a short period of time, the woodchips and the sawdust get pyrolyzed and the pyrolysis gas or volatiles is produced. This volatile gas typically consists of methane, carbon monoxide, carbon dioxide and water. A copper tube with an inside diameter of 0.5" (1.2 cm) and holes along its length is inserted into the gasifier chamber so that it would collect pyrolysis gas and transport it outside of the chamber for experimentation. A silk mantle, similar to the mantle used in Coleman lanterns, is fixed at the other end of the gasifier tube. The gases coming out of the tube are flared off, heating the mantle until it produces light.

A Welsbach Mantle is made of silk rayon impregnated with a mixture of rare earth oxides. The mixture of these rare earth oxides when heated to the right temperature of around 2000 degree Centigrade produces a brilliant while light. The volatiles can be burnt in premixed or diffusion mode. Premixed burning would require a simple premixing device. The secondary air is drawn in at the bottom of the premixing device and it is mixed with the combustible gas. This provides the option for stoichiometric mixture of fuel and air, which helps to give the maximum flame temperature, a little lesser than the adiabatic flame temperature of the gases. In turn, this helps to heat up the rare earth oxide mantle, which produces white light. With the diffusion mode of burning, the mantle has to be adjusted so that the flame touches the mantle and heats it up.

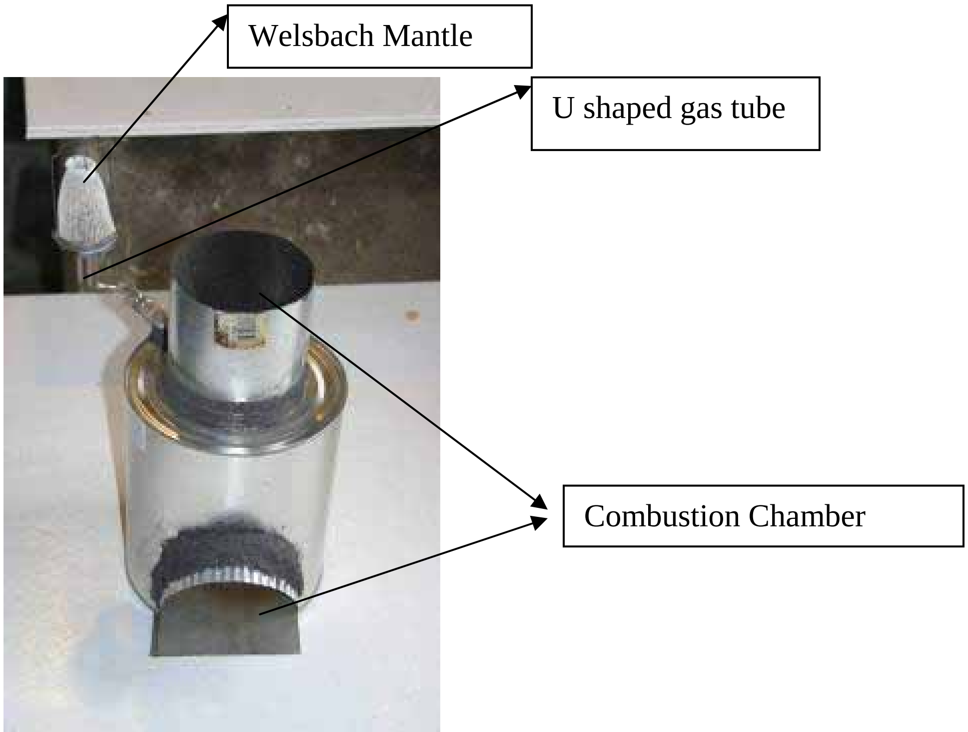


Fig: 1. A prototype of gasifier/cook stove for producing light.

Fig.1 shows the assembly of the prototype of the gassifier-cook stove. Few preliminary tests conducted in Engines and Energy Conversion Laboratory and APROVECHO prove that this method is technically feasible. Furthermore, it requires no moving parts and uses only a simple steel tube with a kerosene mantle, which is cheap and easily accessible. The Nepalese team agrees that this simple technology would be viable and could be proved in the field by its corporation in the cookstoves designed and disseminated by the Nepalese team.

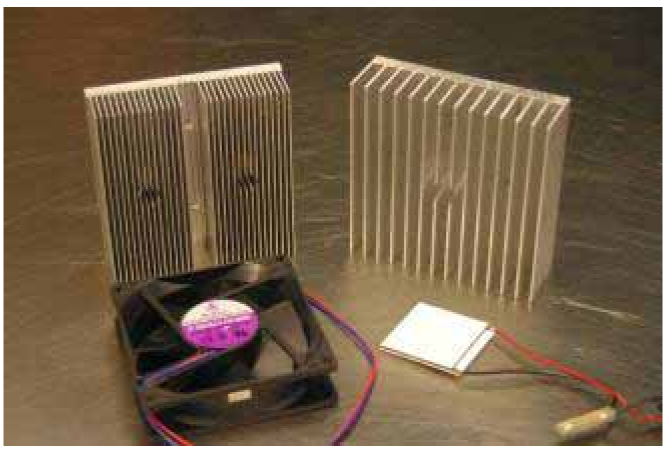
We hope to implement this technology on the cookstove designed by the Nepalese Team (shown on the left). This technology can be used at homes mostly in high altitude regions where people primarily use metal cookstoves. However, it can also be used in other stoves as long as the combustion chamber is made of conducting metals.

(Courtesy: STARIC/Nepal)

(Sushim Man Amatya from Nepal with the newly designed improved cookstove for Khumbu Region)

b) Thermo Electric Generator

A thermoelectric generator is a very appropriate and feasible alternative for making light from stoves. Thermoelectric cells produce electricity when a temperature difference exists across them. These devices are therefore very simple, quiet, and reliable. They typically work best in applications where power output is less than 20 watts. A five-watt module has been selected for testing and further implementation in this work. This module is made by Tiahuaxing in China and could be purchased for around $10 US in large quantities. This module will give two watts of power to drive a fan, and three watts of power to light a high intensity light emitting diode (LED). LED's have been used in other sustainable lighting projects and have become very popular. Although the power consumption is low, they can provide enough light to illuminate an entire room.



In addition to the thermoelectric element, two finned heat sinks (shown on the left) are required to keep the hot side hot, and the cold side cold. These heat sinks will cost around $5 US a piece in large quantity. They may also be made locally for less, which would have an added economic benefit. Two heat exchangers have been selected that can move enough heat through the module to produce the maximum power.

The generator also requires a fan to aid in cooling the cold side. This fan takes some of the power from the module, but it is not wasted power. The fan could serve one of two purposes. First, it could be used to circulate warm air throughout a room. This would make the stove more effective in heating a room, resulting in less wood consumed. The second option would be to use this air in the stove to create cleaner combustion. Many people in the stove community have expressed a need for some sort of forced air to create a much cleaner stove. This is one way of producing forced draft. Several fans have been selected for this application, and are currently being tested to determine which will give the best results.

The entire generator system has been assembled and tested in a laboratory environment to determine characteristics of each component. Fins were fabricated in Engines and Energy Conversion Laboratory. The module, the heat exchangers, and the fan are all being evaluated. Currently, the hot side is being heated with an electric heater, rather than heat from the stove. This is helpful since it can create very steady conditions necessary for taking data. Once the preliminary testing is complete, testing on the stove will begin.

Preliminary tests have been encouraging. After subtracting the power required for the fan, the module is delivering about four watts of power, more than enough to run the LED. A computer model is also being developed to further optimize the system to make it cheaper and more powerful. Figure 2 shows a computer simulation of the heat transfer process through the heat exchanger. Figure 3 shows a CAD drawing of the system, as it would fit into a stove chimney.

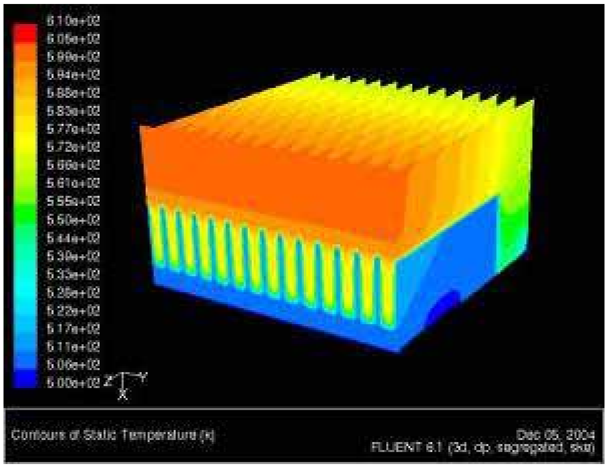


Fig: 2. Computational model of heat exchanger

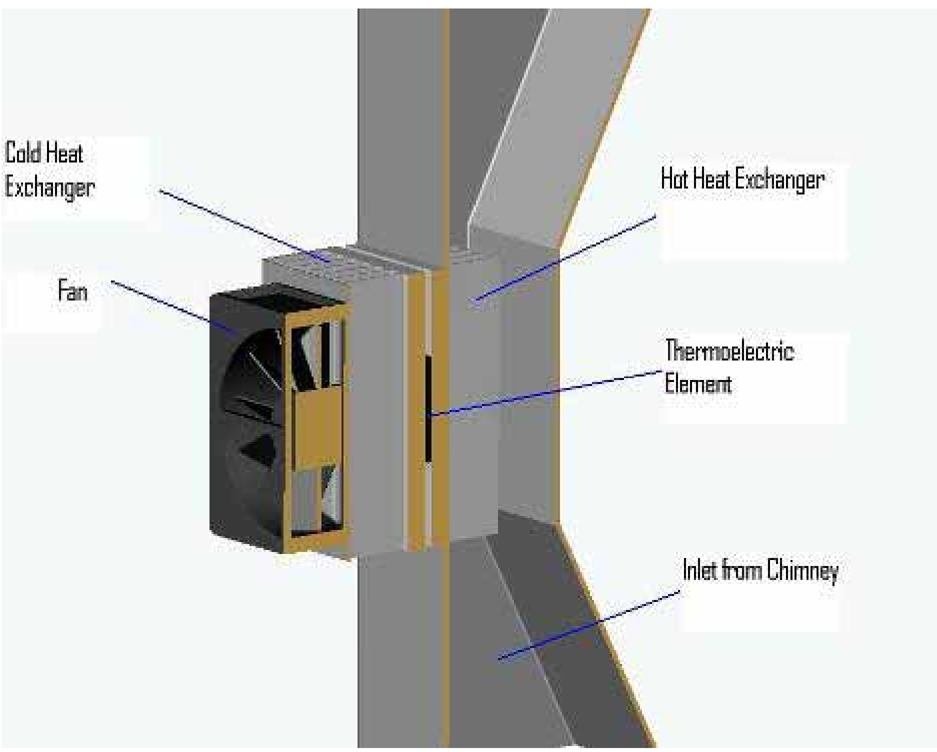


Fig: 3. CAD drawing of generator assembly on stove chimney

Once the generator has been optimized, the next stage will involve real world testing. The generator will be installed in stoves in Nepal to test several aspects of the design. First, the compatibility with the stoves and the users will be determined. It is important that the users find it simple enough to operate that they will benefit from it. It is also important that it can easily be incorporated into existing clean stove designs. Finally, it will be tested for reliability and longevity.

c) Hand Cranking Device for Lighting

A simple mechanical hand crank is another viable solution for light generation. Light can be generated from the mechanical energy of a hand crank, to electrical energy, ultimately to emitted light. Currently, a number of different types of mechanical hand crank generators have been designed for recreational markets consisting primarily of flashlights and radios. These devices range in cost from $30-60 (see picture below). The CSU team shared the cost to buy a similar device so as to find out how they work and whether a design based on this principle could be replicated in a developing world.

"Sentinel" produced by Coleman sells for $35. It uses a mechanical hand crank to generate light. The device can provide 30 minutes of continuous light using a 3.3-volt xenon bulb.

Thus a mechanical hand crank could be produced at a realistic cost. In the past these devices used a mechanical crank to tighten a torsion spring, which was used to store energy mechanically. The spring would then unwind and electricity would be generated in the windings of the armature. Storing energy is advantageous because it eliminates the need for excessive crank rotation to generate a constant light source. However, more recent designs have implored a battery as a means of storing electrical energy generated from a hand crank. The advantage to battery storage is that it is a more efficient design when coupled to a light-emitting load than that of a torsion spring. Nonetheless, considering operating temperatures and conditions, a spring design would be a better means of storing energy because it offers a wide temperature operating range, durability, longevity, and is more cost efficient. Another design consideration would be the implementation of white light emitting diodes (WLED). From data collected by Dr. Dave Irvine-Halliday, a Professor of Electrical Engineering at the University of Calgary, WLED's have been shown to last longer, behave more durably, and consume less power (see table below).

Lamp Type	Homemade Kerosene	Incandescent	Compact Fluorescent	WLED
Efficiency (Lumens/watt)	0.03	5 - 18	30 - 79	25 - 50
Rated Life (Hours)	Supply of Kerosene	1 000	6 500 -15 000	50 000
Durability	Fragile & Dangerous	Very Fragile	Very Fragile	Durable
Power Consumption	0.04 - 0.06 liters / hour	5W	4W	1W
CCT °K	~1 800°	2 652°	4 200°	5 000°
CRI	~ 80	98	62	82
$ After 50 000 hours	1251	175	75	20

The draw back to WLED's is cost. Current high performance WLED's cost roughly $2 a piece; this is twice the price of a regular LED's, and is considerably more than the cost of incandescent bulbs. Conversely, the initial cost is out weighed by the performance gain from WLED's in terms of longevity and durability. In short, a mechanical powered hand crank generator, using a torsion spring for energy storage and WLED's for light, offers longevity, durability, and is economically feasible for light production in Nepal.

Detail design suitable for manufacturing in Nepalese Market has not been done yet.

IV. FUTURE PLANS

a. FURTHER WORK

We further intend to work on developing the proposed solutions. Hand Cranking Device for lighting is an attractive technology. If we can come up with an appropriate design so that it could be manufactured cost effectively with simple technologies available in Nepal, then it would be feasible.

We intend to implement all the proposed solutions in Nepal. The necessary equipment and accessories needed to manufacture the thermoelectric generator, the thermal light system, and/or the hand-cranking device is available in Nepal. We intend to fabricate few parts with the help of Nepalese Counterpart in the Mechanical Workshop in Tribhuvan University for demonstration purpose. The rest of it would be given to a local manufacturing shop.

The future project task distribution shall be as follows:

Nepal Team:

The Nepal team shall be responsible for:

- Identifying appropriate villages in the rural part of the country to implement the project. (Current locations are Dolpa and Sagarmatha Districts of Nepal, but these places may change due to the insurgency of the terrorist groups in some places in these districts.)
- Providing adequate information to the Colorado group. This includes the feasible approaches that can be adapted by the rural people that are affordable and sustainable in the long run and also providing the other group information on technologies that are efficient but not sustainable due to the cost factors.
- The team shall also be responsible for continuous monitoring of the project to know the feedback of the technologies.

USA Team:

The USA team shall be responsible for:

- Lab testing of the explored technologies.
- Providing the data of the tests to the team in Nepal.
- Guiding the team in Nepal to advocate the best technology for lighting.

Ujaylo Team: ("**Ujaylo**" in Nepali means Light)

- The entire team will travel to the villages in Nepal contacted by the Nepalese team for the demonstration and field – testing of the technologies.
- The team will try to forge a closer relationship with each other and the villagers with whom it will be working.

In order to carry out the future plans mentioned above, we have come up with an outline of the tentative implementation cost. The number of households targeted is around altogether 100 in Sagarmatha Region and Dolpa Region. The cost below shows a tentative implementation cost in each household.

b. **TENTATIVE BUDGET:**

S. No.	Technology	Items	Quantity	Unit Cost (US$)	Total (US$)
1	Wood-Gas Lighting	Metal Cookstove	1	30	30
		The gas tube	1	5	5
		Mantle	1	2	2
	Total Unit Cost				**37**
2.	Thermoelectric Generator Lighting	Module	1	10	10
		Fins	2	5	10
		LED	1	4	4
		Fan/Wires	1	3	3
		Electronics	1	3	3
	Total Unit Cost				**30**
3.	Hand Cranking Device	(Manufacturing)	1	30	30
	Total Unit Cost				**30**

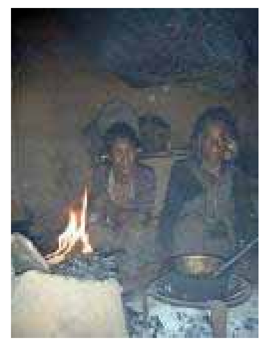
Other Costs:

S. No.	Item	No. of People	Unit Cost	Total Cost
1	Flight Cost – USA – Nepal – USA	5	$1200	6000
2.	In country traveling and lodging	10	$600	6000
3.	Other Costs		$2000	2000

V. CONCLUSIONS

The destitute people in high mountainous regions of Nepal are continuously engulfed in a vicious cycle of poverty throughout their life. No hope of light shines through in their life unless an outsider offers to help them. We intend to be those helping hands.

This project has been a result of a long persistent dialogue and cooperation between the two teams in Nepal and USA. The people who initiated the contact with the team in Tribhuvan University had to leave later on because of their academic engagements. But, as the word got out, other interested students joined the group and finally our **UJYALO** team was formed with students from Colorado State University and Tribhuvan University. Respectable research organizations such as Engines and Energy Conversion Laboratory, CSU, Sustainable Technology Adaptive Research and Implementation Center (STARIC/Nepal) worked with the team to facilitate preliminary testing, collect information and to prepare a base for the dissemination of the technologies for the future.



Our team set out to identify the various problems that could be addressed so as to improve the socio-economic condition of people in Nepal. Every discussion led to our realization that in order to make the lives of people of Nepal better, a comprehensive approach and a coordinated strategy, tackling many problems simultaneously across a broad front has to be pursued by multiple stake holders that includes student, researchers, government, NGOs etc. Among all the problems, one problem seemed to get our highest priority – the indoor air pollution in kitchens. We realized that this was one of the most important issues that people and researchers have been trying to solve for past few decades. Introducing improved cook stoves with chimneys could easily solve this problem. Since, most members of the team had been working in Improved Cook Stoves; we had the understanding of pros and cons of improved cook stoves. The Nepalese team had been working on designing and installing improved cook stoves in Sagarmatha and Dolpa Region of Nepal. Therefore, our team set out to identify the reasons why people still resisted improved cook stoves despite their huge benefits to health and the environment. We realized that the loss of light due to improved cook stoves was one reason why people still tend to use traditional cook stoves.

We then set out to look for possible technological solutions to provide light in the kitchen. There were options such as Solar Home Systems that would light up the home. But, discussion with the Nepalese team showed that these systems were expensive, technically difficult to understand and the subsidies were very much dependent on foreign donors. Our team tried a different approach - to use the cook stoves in the kitchen to produce light. We were able to come up with two technologies that would use the cookstoves in order to produce light. The first was light from pyrolyzing the biomass in the cookstoves to be burned in a mantle. This produces white light as well as charcoal that can be again used for cooking purpose. Thermoelectric Generator is another technique that we have developed. This would require importing the generator module. The fins can be manufactured and assembled in a local workshop. The electricity produced can then be used to power a white LED and also to run a fan in a cook stove so as to increase the combustion efficiency of the stove. This would decrease the fuel consumption and decrease the emission level. We have finished our preliminary testing in

Engines and Energy Conversion Lab and we plan to test these technologies in the field together with the Nepalese team.

Nepal and Colorado are at two opposite time zones with 12 hours difference. Furthermore, CSU is one semester ahead of Tribhuvan University. Therefore, when one team was free, the other team would have their finals and exams and vice versa. This put the two teams pretty much out of contact for few months during exam seasons. And often, the Nepalese team would have long holidays due to national festivals. Since, Sushim, Rajeev and Pawan were from Katmandu, we could keep in touch with each other through email. Kiran and Bishnu were from outside Katmandu and the telephone/internet was not available or damaged at their places due to the Maoists. Telephone Calls were a luxury but we did manage to place few phone calls in Kathmandu either when it was very late in Colorado or when it was too early in CSU because of the twelve-hour time difference. Language did not become a problem because all the team members spoke English. Emails and MSN messenger service proved to be our best method of communication. EWB/CSU forum (www.engr.colostate.edu/ewb) was also frequently used to post some of our messages and the email contents. It took us a very long time to organize an effective team here in CSU and TU at the start. Correspondence between the two teams was slow at the beginning because none of them knew each other. But, few phone calls afterwards did make everyone comfortable. The identification of a problem to work on was another issue that divided the team. During the proposal submission in February, we had a vague idea that we would be working on an issue that would incorporate water, biomass, energy and health. The people who worked on the earlier proposal had to leave because of their graduating in Spring 2004. That created a temporary stall in the development of the project. However, things started to roll in when Sachin from Nepal and Dan from Colorado, both studying in CSU, became involved in the Mondialogo Project.

Ultimately, all of us in the team did enjoy working together. We have come up with solutions that would be able to help the people in mountainous regions of Nepal to improve their socio-economic conditions. The security of household livelihoods rests on the health of its members. Being ill or having to care for sick children reduces earning capabilities and leads to additional expenses for health care and medication. Bringing lighting allows children to study outside of daylight hours and without putting their eyesight at risk. This is what we hope to achieve with the implementation of our proposal.

There is a huge difference in the living standard between the people in Colorado and Nepal. We cannot change the world overnight. But, by building strong friendship and collaboration between the teams from developed and underdeveloped country like US and Nepal respectively, we hope to make the future bright for all of us. Besides the beautiful mountains that our “UJYALO” team in Colorado and Nepal enjoy, only one thread links our two teams together – the spirit and commitment to help the people in need and we shall continue our new friendship and explore different ways to help each other.

APPENDIX

I. MEMBERS INVOLVED

The following teams are involved in this project.

Country: Nepal

a) Sushim Amatya – Engineers Without Borders / STARIC- Nepal
b) Rajeev Shrestha – STARIC/Nepal
c) Kiran Gautam – Tribhuvan University
d) Bishnu Acharya – Tribhuvan University/Nepal
e) Pawan Shrestha – Engineers Without Borders/STARIC - Nepal

Country: USA

a) Dan Mastbergen – Colorado State University
b) Ryan Shannon – Colorado State University – Engineers Without Borders - CSU
c) Roberto Arranz – Colorado State University (Spain) – Engineers Without Borders - CSU
d) Sachin Joshi – Colorado State University / Engineers Without Borders - CSU

EMAILS

(Attached in the original hard copy of the proposal)

FEW INTERESTING PHOTOS

Dan experimenting with the thermo electric generator in Engines and Energy Conversion Lab, Colorado State University

Dan trying to stabilize the burning pyrolyzed Gas in APROVECHO