# Smoking Barrels:
# Searching for Sustainability
# In Khumbu's Kitchens

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## Abstract

This thesis presents a case study of energy use—primarily wood and yak dung—in Nepal's Khumbu region. The case study describes local patterns of energy use and provides explanations for these patterns. Suggestions for reducing the amount of wood and dung burned for energy in the Khumbu are offered. The conclusion is that a large reduction of woodfuel will require increasing energy alternatives, and providing an alternative infrastructure for heating.


## Introduction

With darkness still hiding the brilliance of the world's largest and most magnificent mountains, Ang Sherpa steps out of Hidden Village Lodge and into the bitter cold air of Khumjung, a central village at 12,000 feet in Nepal's rural and mountainous Khumbu region. She uses a hand-made axe to chop wood, which is put in a bucket and brought inside. She lights the wood in an iron stove in the middle of the eating room. The stove will be refilled three or four times over the next few morning hours. In the kitchen a second wood stove is lit. After another Sherpa woman collects water, several pots are put on top of the iron stoves. When the waking trekkers enter the warming room, the two women begin to prepare breakfast. If there are only a small number of trekkers—less than six—the two women will only need the wood burning stove and the two electric burners to cook breakfast. With more people, food will be prepared on the electric burners, as well as on one or both of the kerosene stoves, and the wood burning stove.

After breakfast the stove in the eating room dies out. The stove in the kitchen, however, is continually fed with wood throughout the day. The stove is kept burning so that water can stay warm for tea, and a quick lunch can be made for a trekker passing by in the afternoon. Sometimes—on particularly slow days—the stove, and thus the room, goes cold. This leaves lunch to be prepared on the two electric burners, which, even though convenient, cannot keep water warm, and are often insufficient for making a big meal. More importantly, the electricity, which comes from a 600kw hydro project five miles west in Thame, is needed to supply all local villages, so electrical energy is extremely scarce. Ang must use her four kilowatts wisely. Kerosene is rarely used during the day as it has similar disadvantages but is also messy, smelly, and more difficult to use than the electric burners.

Around four-thirty in the afternoon, as the snow on the Himalayan Mountains turns a fiery orange, the two wood stoves once again burn in full force to heat the lodge. Dinner is cooked using any number and combination of fuels and stoves. The kitchen's wood burning stove is primary for cooking and water heating, while the two kerosene stoves and the electric burners are used secondarily, though frequently. As will be illustrated in great detail later in this thesis, these shifting patterns of energy use can be explained by the advantages and disadvantages of each source of energy, and the limits facing each type of resource. Acquiring the energy to provide heating, cooking, and lighting is a difficult, time consuming, and expensive task for the people of the Khumbu.

These patterns of energy use, and the scarcity of the sources, are not unique to the Khumbu. Biomass fuels are the fundamental source of energy for rural areas around the world (Amacher, Hyde, and Kanel 1999; Schramm 2001; Allen, and Barnes 1985). According to a recent study, "Half the world population and 80 percent of rural households in developing countries cook with solid fuels like wood, coal, crop residues and dung" (Haag 2008, 1). Rural communities' dependence on biomass fuels—primarily wood—plays an enormous role in determining the quality of life for these people. Scarcities imply that energy will be very expensive or time consuming to acquire. Furthermore, the indoor use of biofuels is an enormous health hazard to those who inhale the smoke.

In addition to these social and health problems, the use of biomass fuels is also causing ever increasing environmental problems such as deforestation and global climate change. Reliance on biomass fuels in the world's rural areas clearly has huge implications for the quality of life of millions of people, as well as for the health of the environment. It is my thesis that, to improve the quality of life for people living in rural mountain villages, and to ensure that the world's natural environment is protected, the burning of biomass for energy must be significantly reduced.

As has been witnessed repeatedly in many projects designed by the International Monetary Fund, which often come attached to their loans, development work is unlikely to succeed if it is not based on the conditions, realities, and the environment of the project area. Projects to reduce the burning of biomass energy, of which there are many, are greatly benefited from studies of energy that illustrate local patterns and explanations. This contribution of this thesis is a case study of energy in the Khumbu region of Nepal, where such a study has not yet been done. The case study should be used in the future to help design a project to reduce biomass fuel use in the Khumbu.

The literature review section of this thesis examines many other studies that have been done on energy in rural mountain villages. Because studies for the Khumbu region are very limited, the studies examined will be from various locations—the Khumbu, Nepal, many African countries, as well as others. The literature review identifies the patterns of energy that can be found in rural mountain villages around the world. It also highlights factors that commonly govern the patterns of energy, many consequences of them, as well as some solutions to rural energy dilemmas.

The case study of energy in the Khumbu presented in this thesis is based on the research that I did there in the fall of 2007. The study provides an incredibly detailed account of the patterns of energy use in a string of central and eastern villages in the Khumbu. In illustrating the patterns of energy and revealing the reasons why wood and dung are used, this thesis presents original and grounded implications for how the Khumbu could reduce biomass fuel use in the future. The case study is divided into two sections. In the first section I address the question, *what are the specific patterns of energy use in Nepal's Khumbu region?* In particular, what sources of energy are used for what purposes? As will be explained, wood and yak dung are the primary sources of energy, which are used for heating and cooking. At higher elevations, wood is used less, while yak dung and kerosene are used more. The second set of questions addresses *why* those patterns of energy use are the way they are. For example, why do lodges only use electricity for cooking in the summer, and why do villages at higher elevations use kerosene so much? These patterns are largely explained by government regulations on wood collection, as well as by the limitations of kerosene and electricity. These explanations also illustrate why biofuels are the principle form of energy in the Khumbu. The main findings are that wood and yak dung are needed because of the lack of available alternative energies, as well as the lack of an alternative infrastructure for heating.

Following the case study I discuss the larger implications for the future of energy consumption in the Khumbu. What the case study implies is that significantly reducing the amount of wood and dung used for energy will require an increase in alternative energy as well as an alternative infrastructure for heating. Future research should use the findings from the case study of energy patterns, and its implications, in order to devise locally appropriate methods for supplying alternative heating infrastructures and providing additional energy.

**Literature Review**

Despite a large number of studies that have been undertaken, developing an accurate account of the annual amounts of wood burnt (for fuel and for other purposes) is difficult to achieve. Meinrat O. Andreae (1990) provides one of the most complete quantitative studies on the burning of biomass resources. He suggests that nearly three trillion pounds of wood is burned globally each year solely for fuel. Over 90 percent of this wood consumption occurs in the developing world. On average, 80% of rural households in developing countries cook with solid fuels (Haag 2008).While exact numbers vary between studies, it is clear that biomass fuels are the primary source of energy for rural households in developing countries, which are used primarily for heating and cooking (World Bank 1979, 2005; Ali, and Benjaminsen 2004; Amacher, Hyde, and Kanel 1999; Allen, and Barnes 1985; Andrews 1983; Bachmann 1983; Schramm 1989).

For instance, a study of wood fuel in Africa shows that many of the Sub-Sahara countries rely on wood and biomass for around 90% of their total energy consumption (Schramm 1989). A slightly older study suggests that a number of African countries rely on wood fuels for 95% of energy consumption (Allen, and Barnes 1985). Similarly, in Pakistan woodfuel is the main source of energy for 70-79% of households. It provides about 53% of all energy (Ali, and Benkaminsen 2004). In Nepal, different studies report similar numbers for energy supplied from woodfuel. A 1979 World Bank study suggested that 90% of Nepal’s energy came from burning wood. Shallgram Pokharel calculated in 2001 that this number was closer to 80%. These numbers for Pakistan and Nepal, however, represent an average across the whole country. Rural households rely on biomass for energy far more than urban households (Andreae 1990; World Bank 1979). For example, a 2006 World Bank study of Nepal suggests that 95% of energy for rural houses is met from biomass fuels, with 75% from woodfuel, and the remaining 20% from combustion of agriculture residues and dung.

Though most rural areas in developing countries rely dominantly on biomass fuels for energy, there are an increasing number of energy alternatives that can be found in these remote areas. Most of these alternatives, however, produce carbon emissions. As of 2001, most African countries have yet to see any real development in alternatives to wood. Only a few countries have crude oil resources (Angola, Cameroon, Congo P.R., Gabon, Nigeria, Zaire). However, many that do have to export due to the absence of a refinery. A few others have coal (Botswana, Zimbabwe, Zambia, Tanzania, Swaziland, Mozambique); though, most often the supplies of coal are far from the demand. Even in urban areas, fewer than twenty percent of houses have access to electricity. Rural villages, on the other hand, have practically no access to electricity. The most prominent alternative to wood is Kerosene. Nevertheless, supplies of kerosene are very small, and are often in shortage. (Schramm 1989).

There are very few studies that describe specific patters of energy use in the Khumbu, especially for patterns of energy sources other than wood and yak dung. A study on hydropower in Nepal is the only systematic study of this region. It states that, "At present, Nepal's demand for electricity is just over 350 MW, while current capacity from hydropower stations is 250MW…and 51 MW from diesel units, thus totaling some 300 MW. Only about 15% of the population has access to electricity, and the average per capita consumption is among the lowest in South Asia. The deficit in energy supply is met by importing petroleum products for household and industrial consumption and power generation as well as clearing more forests and providing access to alternative sources such as solar power" (Pokharel 2001, 1).

This section will highlight the many factors that govern energy use patterns in general. Before discussing these most frequent constraints on energy, it should be noted that population growth greatly exacerbates the difficulties discussed here, of adopting alternative energies (World Bank 1979; Amacher, Hyde, and Kanel 1999; Schramm 1989). One of the most obvious factors that regulates energy use is price. In many rural villages substitutes for woodfuel are more expensive, and thus, unaffordable or unfavorable for consumers. Even when alternatives are available, the relatively high cost sends people back to traditional sources of energy. For example, in the World Banks 2005 Millennium Development Goals Progress Report for Bhutan, the conclusion is that, "A single Bhutanese on average consumes 1.27 cu.m of fuel wood a year, which is regarded to be among the highest in the world and is explained by the fact that it is more accessible and affordable that other sources of energy" (67). Another study of woodfuel in the Himalayas states that "This reliance on fuelwood is expected to remain high in Pakistan in the foreseeable future, mainly because the country's economic development is not strong enough for a shift from traditional to modern fuels" (Ali, and Benjaminsen 2004, 1).

The costs of alternatives can be higher for a number of different reasons. In many cases, when examined on the basis of per unit of energy supplied, alternatives are more expensive than traditional energy sources. This is the case for electricity and natural gas in most African countries (Schramm 1989). In other cases it is the increasing price of oil that is preventing an energy shift (Allen, and Barnes 1985). And while kerosene is thought of as "the poor man's fuel" in many African countries, it cannot serve as a replacement for woodfuel. Replacing woodfuel with kerosene would hugely increase petroleum imports for African countries (75% in Tanzania), which already constitutes a large percentage of total export earnings (51% in Senegal, and 53% in Ethiopia) (Schramm 1989). In short, this substitution would dramatically increase already significant foreign exchange deficits. Nepal faces a similar problem. In 1999/2000, petroleum imports constituted 40% of export earnings. This is a level of importing that cannot be sustained (Pokharel 2001).

Another aspect of cost that is continuing to drive the use of traditional biomass fuels is the price and availability of appliances. "For the most part, the choice of a particular type of capital equipment for heating ties the consumer to a particular type of heating fuel. An electric heating system cannot burn natural gas or fuel and a wood stove does not use electricity" (Bryant 1986, 72). So if rural villages currently heat and cook with wood, the cost of switching to electricity, natural gas, or another alternative would cost the consumer much more than just the price of the energy itself. For example, even where coal and electricity are available in African countries, "the costs of appliances for their use are far too high for households" (Schramm 1989, 63).

Cost plays a big role in determining what sources of energy are used. But how "true" are the costs that people are paying for wood? For example, consider forest management in Africa where "uncontrolled exploitation of remaining forest resources is the rule rather than the exception in almost all countries" (ibid, 62). In Africa, the cutting of wood is illegal, so neither the land from which the wood is cut, nor the wood itself is owned by the people who cut it. As a result, "there is no incentive for long-term management that would lead to sustainable production of wood, nor is there for the maximization of yields" (ibid). Rather, forests are exploited without replenishment, and thus the costs are kept artificially low because they reflect only the cutting, and not the additional ones that would occur from replacement. Eventually, "supplies will dry up practically overnight, shortages will occur and prices will rise drastically" (ibid). Evidently the market prices for wood in Africa do not reflect this growing scarcity, and as such it is helping prevent a switch toward alternative energies. This is something to keep in mind for the later discussion of solutions.

The last factor which affects patterns of biomass fuel use is availability. Amacher, Hyde, and Kanel (1999) provide an extensive study of the effects of woodfuel scarcity on household behavior in Nepal. They conclude that, particularly in remote hill regions, woodfuel collection and use "is significantly (although inelastically) responsive to the level of resource stock and to its accessibility. Therefore, the availability of the hill stocks constrains the final level of fuelwood consumption by these households" (158). They confirmed these findings by observing increased energy substitutes as woodfuel became scarcer. Another study reports the same findings in Pakistani villages. "The people in villages situated near the forest consume more wood compared to the villagers situated at a further distance" (Ali, and Benjaminsen 2004, 315).

The sections above discussed general patterns of energy use in rural mountain villages around the world. These things, however, vary greatly from country to country and must be understood with respect to each individual place in order for an energy project to be successful. Meanwhile, the major consequences of using biomass fuels can be very similar between different regions. For instance, there are a huge number of studies that link woodfuel use to indoor air pollution, deforestation and carbon emissions. Additionally, there are studies that detail the affects of each of these things, and their associated harms.

It has been widely shown that demand for wood fuel is a leading cause of deforestation in developing countries around the world (Ali, and Benjaminsen 2004; Allen, and Barnes 1985; Andrews 1983; Karan, and Iijima 1985; Bachmann 1983; World Bank 1979; Schramm 1989). Also well documented are the many negative affects of deforestation, which include increased landslides, erosion of valuable fertile topsoil leading to loss of cultivable land, and siltation which causes increased floods (ibid).

Aside from issues of deforestation and its deleterious effects, the use of biomass fuels has likely even greater consequences which results from the effect it has on the atmospheric carbon dioxide budget ($CO_2$ budget). On a long enough time scale the $CO_2$ budget is not influenced by biomass burning, as long as new growth replaces the old and absorbs the same amount of $CO_2$ (Andreae 1990; Potter 1999). However, the deforestation from the clearing of forests in many rural areas is adding enormous amounts of $CO_2$ into the atmosphere, and contributing directly to the greenhouse effect and to global climate change (ibid). One estimate from 1990 suggests, for instance, that the $CO_2$ released from biomass burning constitutes 40 percent of the world's total $CO_2$ emissions (Andreae 1990). In addition to $CO_2$ emissions, there are numerous other gases and particles that are released by traditional biomass combustion; these include carbon monoxide, hydrogen, methane, nitric oxide, ammonia, and sulfur dioxide (ibid).

The release of these gasses and particles into the atmosphere will have serious consequences in the long run. Before they are released into the atmosphere, however, these toxins reach their highest concentrations indoors, which has equally serious consequences today. The indoor air pollution resulting from the combustion of biomass fuels is a leading cause of illness and premature death for woman, young children, and infants (Haag 2008; Hessen, Schel, and Pandey 2001; World Bank 2006). While exact numbers vary between studies, it is estimated that indoor air pollution is responsible for between 1.6-1.8 million additional deaths a year. This problem falls disproportionately on women and children.

There are clearly important negative environmental and social consequences which result from the burning biomass fuels for energy. In light of all of the problems, there have been many efforts to reduce the amount of biomass fuels used in developing countries. There are multiple ways to go about reducing the use of biomass fuels. Obviously biomass fuel could be reduced through simple command and control regulation. That is, the government could make the harvesting or consumption of wood illegal. Regulations like these would be very problematic for people living in poor rural villages where energy is tremendously scarce. Furthermore, these laws might not be followed, as is certainly the case in most African countries where the cutting of wood is often illegal (Schramm 1989).

Another way to reduce the amount of woodfuel used is by improving the efficiency of the burning process; in other words, by getting the same amount of energy out of a lesser amount of wood. This is most commonly done with improvements in stove technology. Improved stove technology can be the transition from open fires to traditional iron stoves, from traditional iron stoves to even newer cleaner wood burning stoves, or a number of other possibilities. Studies have shown that small improvements in stove technology can easily lead to ten percent increases in the percentage of carbon that is burned to carbon dioxide (Haag 2008). For instance, Hessen, Schel, and Pandey (2001) found that people living in rural areas of Nepal are accepting of newer stoves and are willing to pay 8% of their annual income to have improved stoves installed. A 1989

World Bank study of African countries argues that given the limitations of current alternative energies, improved stoves combined with better forest management plans is the best way to reduce the use of biomass. These options, however, are end of pipe solutions that don't fix the fundamental problem—which is the use of wood for fuel.

A third way to reduce the consumption of biomass fuels is by replacing them with alternative energies. This paper argues that this is the best way to achieve the reduction. Consequently, further discussion on methods for reducing biomass burning will be based on the provision of alternative energies that can replace woodfuel as a source of energy.

As discussed above, one of the main things preventing a shift from traditional energy to modern energy is the higher cost. However, as wood becomes scarcer the opportunity cost of labor and collection will eventually become higher than the price of alternative energy fuels (World Bank 1979). The relative increase in price of wood, however, is not a good solution by itself. Alternative energies need to make sense, not just be the least of evils.

While cold temperatures in the Khumbu prevent the system from being viable, one major source of alternative energy in warmer areas of Nepal comes from biogas (Bachmann 1983; World Bank 2006). Biogas reactors collect the methane and other gasses that are released from the decomposition of yak dung and other organic matter that are trapped in an air tight chamber. The Government of Nepal, with assistance from the Netherlands and Germany, has provided over 150,000 biogas reactors. This amounts to considerable reduced wood use considering that each biogas reactor saves each household about 450 kg of firewood and 6 liters of kerosene per cubic meter plant size each year (World Bank 2006). Furthermore, biogas reduces indoor air pollution, as well as greenhouse gas emissions (ibid).

Though only in urban areas, passive solar water heaters have been established devices in Nepal since the early 1980's (Bachmann 1983). A water heater with the surface of 1.7 square meters of collecting area warms 100-120 liters of water to approximately 150 degrees Fahrenheit (ibid). Passive solar water heaters are an example of a simple yet successful way to reduce consumption of biomass fuels.

Currently, the greatest opportunity for Nepal to reduce its consumption of biomass fuels is through the development of hydropower projects. As the major sub-basin of the Ganges, which contributes 220 billion cubic meters per year, Nepal has a huge potential for hydropower (Pokharel 2001). This amount of water flowing down the steep hills of the Himalayas could produce up to 83,000 MW of hydroelectricity (ibid). "Therefore, a judicious exploitation of water resources could advance social and economic development in Nepal and help diminish pressure on the country's overexploited forest resources" (ibid). Furthermore, while small rivers are suitable for small scale projects to replace kerosene for lighting, larger projects could provide the basis for huge export earnings (ibid).

Through the review of other studies, this paper has so far drawn a general picture of patterns of energy use in developing countries and rural villages, and the factors that govern those patterns. It has also looked at the consequences of burning biomass fuels for energy, as well as some solutions to those problems. In order to design a project to reduce the use of biomass energies, a study must be done that intricately describes these patterns and realities with respect to the particular location of the project. The case study presented in the next section of the paper is going to illustrate in great detail these energy patterns and causal factors in the location of the Khumbu, for where there is no such study currently available. With an understanding of why biomass fuels are used in the Khumbu, the subsequent section will briefly discuss the implications for how to reduce biomass fuel use.

## Case Study

### Methodology:

The data from the case study comes directly from the research project I did in the Khumbu during the fall of 2007. I spent three and a half months in Nepal, and a month and a half in the Khumbu. I collected data on the Khumbu patterns of energy and the causal factors through a combination of interviews, village surveys, and onsite observations. I documented patterns by moving through the string of villages starting in Benkar at 2900 meters, going up north northwest to the highest village, Gorak Shep at 5160 meters, just shy of Everest base camp, and then back down. In every village I visited, I collected data on every house and every lodge. This includes information on supplies of wood and dung. For the houses that I lived in I did more in depth data collection, as well as interviews. Speaking only in Nepali, I first asked people about where their fuels came from, how they acquired it, and how much it cost. This included information on government regulations on wood collection. Later I would ask about how they used their fuels: for what, when, and most importantly, why.

In the following presentation of this data, the names of the people I talked to and the names of the lodges have been changed, except for the case of Tenzing Sherpa and Ang Sherpa who own Hidden Village Lodge in Khumjung. Tenzing Sherpa (who speaks good English) is a board member of the Khumbu Bijuli (electricity) Company, and in 2007 he received the Khumbu Community Service and Conservation Award for his role as chairman of the Sagarmatha National Park Buffer Zone Management Council. Tenzing was a fundamental source of information to me in completing my study. As someone whose job it is to understand and present these issues, Tenzing helped me document the patterns of energy, the government regulations on wood collection, and the past and present local energy projects, most of which he is organizing.

**What are the patterns of energy use, and what are wood and dung used for?**

Most visitors to Nepal's Solu-Khumbu fly into Lukla, the highest paved runway in the area (see appendix A for map). Technically Lukla is in Solu, the region south of the Khumbu. From Lukla, a one or two day walk up hill and north leads to Namche Bazaar at 3500 meters, which is where the Solu turns into the Khumbu. The two regions, however, have vague borders and are very connected to each other by the Dudh Koshi River. From Namche Bazaar there are three main trekking paths that lead to higher elevations into the heart of the Himalayas. The most traveled path follows the scattered villages leading north northeast, which is chosen path for this study. Second to that is a path leading through villages directly north. And the least traveled path heads northwest. One notable pattern following the route for this study, NNE, is the size of the villages. Every village from Khumjung up gets smaller in terms of the number of houses and lodges. With only one or two exceptions, this pattern is also persistent along the other two trekking paths.

In all the dozens of villages in the Solu-Khumbu, almost all lodges and houses, with exception of very old buildings, are built the same way, using the same materials. There are many other common characteristics and routines that can be found in the lodges and houses of the Solu-Khumbu.

The insides of the buildings are all wood. Outside of the wood structure are stacked granite rocks called ‘dungas,’ which are pounded out of the ground and hand chiseled into rectangles of about 2x1x1 feet. Except on bathrooms and really old houses, the dungas are covered with either a thin layer of concrete or mud, or simply plastered together with mortar. Aside from the structural purposes, the dungas also serve to heat the buildings. During the day the rocks absorb heat from the sun, and then radiate that heat into the house at night when the temperatures drop. Roofs are almost uniformly green tin with rocks on top to keep them in place. Only a few of the oldest houses still use woven straw material for the roof. Recently, many lodges and houses have been putting insulation foam in between the wood and the dungas, and old mattress material above the ceiling, beneath the tin roof. This greatly reduces heat loss at night.

Sherpa homes have abundant space. Kitchens are big, but poorly ventilated, and generally have few windows. All lodges and even small houses have huge eating rooms on either the first or second floor if there is one. These rooms are surrounded with huge windows on three sides, always on the east and south aspects. During the day these windows let in the sun's heat to warm the room. Many of the newer lodges are also passively heated through skylights on the ceiling. At night the windows are covered with thin cloth curtains that prevent barely any warmth from leaving.

In the center of the eating room of every lodge in the Khumbu is an iron wood burning stove that is used for heating the rooms. They are also used secondarily to heat large pots of water. These stoves have pipes that channel smoke out through the chimney when wood or dung is being burned. In the kitchen of every house and every lodge (except in Gorak Shep) is another wood burning stove, generally much bigger than the ones found in the eating rooms. Wood is fed in through an open end of the stove. Yak dung is occasionally burned in these stoves to heat water, but not to cook food with, as that makes it taste bad. The blazing fire inside the stove turns the large iron top into a massive hot plate for cooking and heating. Sometimes there are holes in the top of the stove which provide an especially hot spot for cooking. Instead of connected pipes for ventilation, these stoves have large drafts above them with a hole that leads up through the roof. These poor ventilation systems leave kitchens thick in smoke.

Although burning wood and yak dung in these stoves represents the primary source of energy for people in the Khumbu—mainly for heating and cooking—there are several other important sources of energy used throughout the area, including electricity, kerosene, gas, sun, wind, and water. The largest source of electricity in the Khumbu comes from small hydroelectric projects. The biggest one is in Thame; it produces 600kw that is shared between many villages. There are also many micro hydro units that supply between 5kw and 50kw to very nearby locations. Because of the existing infrastructure, this small amount of electricity is used scarcely between hotplates for cooking, metal coils for shower water heating, lighting, and the occasional outlet—almost all of which can only be found in lodges. Most of the electricity for the few fluorescent bulbs, however, comes from small solar panels that nearly every lodge has. The use of these different sources of energy is complex. As will be illustrated later, they are highly limited by restrictions on all of the energy sources.

*BENKAR*

Heading north from Lukla, there is a small village at 2900 meters, Benkar, that is one of the last stops before reaching Namche Bazaar. At the Sherpa Lodge there lives a middle-aged woman, her husband, and their 12-year-old daughter. The woman's husband, though, is a trekking guide, and is gone for a large part of the year. The kitchen is filled with smoke from the wood logs that burn in the stove all day long, heating the room, and keeping water hot for any trekkers who stop by for hot food or drink. Heating up the iron stove takes a long time, so it is fed wood for most or all of the day so that food can be cooked without warning. The two wood burning stoves—the one in the kitchen and the one in the eating room—are the only stoves in the lodge. Late in the afternoon the freezing air in the eating room surrenders to the warmth that surges out of the stove when the logs are lit with a cup of gas at 4:30pm. Shortly thereafter, a large pot of water is put on top of the hot eating room stove, and the thin curtains are pulled across the giant windows. The stove is filled with logs four or five times throughout the night, then dies out around 9:00pm. There are small compact florescent light bulbs in the eating room and in each of the bed rooms. The electricity comes from a solar panel on the roof. This one small panel captures only enough energy to provide lighting a few days a week. Candles are a more common and reliable source of light.

*KHUMJUNG*

A one to two day walk from Benkar leads to Khumjung, only a short walk above Namche Bazaar. Khumjung is a large and central village where many tourists will stay for several nights or more. Unlike Namche Bazaar, which has high speed internet and is almost entirely based around tourism, Khumjung still subsides on the three traditional ways of life, agriculture, livestock, and trade. Walking into Khumjung, one is immediately greeted by Hidden Village Lodge, owned by Ang Sherpa and Tenzing Sherpa. Tenzing is the major overseer of energy supplies in the Khumbu. He has been working for many years getting funding for hydro projects, and he is in charge of getting supplies of Kerosene flown in from Kathmandu.

Hidden Village Lodge is typical of those in Khumjung. It is twelve years old, there is a huge eating room surrounded by windows, with a stove in the middle of it, and a kitchen with an enormous, table sized wood burning stove. In a separate building there are twenty two-person bedrooms. Outside there is a sitting area with pink plastic chairs. Next to this sitting area is a massive storage of wood that would last a couple years if it was never replenished. In the storage there are ten walls of wood, each of which are five or six feet tall, and seven to ten feet long. During the busy season, around 20 pounds of these logs are burned in the eating room stove starting around

4:30pm, burning until around 9:00pm. This source of heat also brings at least seven or eight big pots of water to a boil. Very rarely is wood burned in the eating room stove in the morning.

In the kitchen Ang, an 18-year-old female helper, and sometimes Ang's 10-year-old son cook food in the hazy but warm room. Every morning logs are set ablaze in the kitchen's stove, both for cooking and for heating. The smoke bleeding from the logs at the open end of the stove is rarely captured by the draft and escorted through the hole in the roof. After breakfast the stove is fed wood at a much slower rate, just enough to warm pots of water. Through out the day the stove generally remains on low. Only occasionally—on the slowest days—does it get down to a smolder. At night the stove burns in full force. In a single day during the winter trekking season the lodge uses around fifteen or twenty kilos of wood.

In addition to the wood burning stoves, Hidden Village Lodge has two kerosene stoves and two electric burners. The wood burning stove is the principle of all three. It is used constantly through out the day, it heats, and it is used to cook several large dishes at once. The electric burners, though only used for small, fast, and simple things, are used with great frequency every morning, afternoon, and evening. Kerosene is almost never used in the morning or afternoon. Only on nights when there is a lot of food to be cooked are the kerosene stoves used. Most days they aren't used at all.

Electricity for Hidden Village Lodge, and for other lodges in Khumjung and its neighboring villages—Khunde, Namche Bazaar, and Thame—comes from a 600 kilowatt hydro-electricity plant in Thame. The villages supplied with this electricity use it for lighting, outlets, and cooking. Additionally, lodges use this electricity to heat water for the tap and for showers. This is done with electrically heated metal coils submerged in the water tanks.

As explained to me by Tenzing, the habits of energy use at Hidden Village Lodge are similar to those found in the rest of Khumjung's lodges. Wood is the dominant form of energy used for heating and for cooking. Electric burners are used very frequently for small things, and kerosene is used infrequently. Nineteen of the twenty-seven lodges I observed in Khumjung had only piles of wood outside (see chart on page 28). Eight had collections of wood and yak dung; and no lodges had only yak dung. Compared to lodges however, houses in Khumjung displayed large numbers of yak dung collections. Only seven of the thirty-four houses I observed had just wood piles. Five houses had only yak dung, and twenty-two of the thirty-four houses had both wood and yak dung collections. Houses in Khumjung do not own kerosene stoves. As an exception to other villages in the Khumbu, many houses in Khumjung, Khunde, Namche Bazaar, and Thame own electric stoves and water heaters because of their easy access to the electricity coming from the Khumbu's largest hydro development in Thame. Most houses, however, only use their electric stoves in the summer when they do not need to heat their houses with wood stoves that also work for cooking.

*PANGBOCHE*

From Khumjung, another one or two day walk northeast leads to the village of Pangboche. At the southern entrance to Pangboche is Namaste Lodge, built in 2006. Even on a cold day, the lodges upstairs eating room is filled with passive heat from the sun. Only slightly smaller than Hidden Village Lodge, Namaste Lodge has a similarly huge storage of wood. Next to the wood, the lodge also has hundreds of dried yak dung patties. Around 4:30pm, the stove in the eating room is packed full of these yak dung patties and lit with a cup of kerosene. The stove is refilled with dung around a half dozen times every night, and it goes cold sometime after nine o'clock. Ten hours later, however, at around 7:00am, dung is once again used to warm the freezing bodies of the foreign trekkers and the local porters who slept there that night. Very rarely is wood used in the eating room stove.

Every morning in the kitchen two women prepare breakfast using a combination of the wood stove, two electric burners, and sometimes a kerosene stove if there is a lot of food to make. The power for the electric burners comes from a nearby micro hydro project. In contrast to Hidden Village Lodge in Khumjung, the kitchen's wood stove at Namaste Lodge uses small amounts of yak dung, and is burned conservatively—mostly for the purpose of heating the kitchen and heating pots of water. Food cooked over yak dung often tastes bad. Much of the morning's cooking is done on the electric burners, and sometimes on a kerosene stove. Late into the morning the wood stove dies down almost entirely. During the afternoon, food and water are prepared using only kerosene and electric burners. In the evening the wood stove is again fired up for heating and is used in combination with, or secondarily to the electric and kerosene stoves. One gallon of kerosene usually lasts for five days. Without the ten kilos of wood that are used everyday, however, that same amount would only last two days. Most of the lights are powered by small solar panels on the roof.

Eleven of the fifteen lodges in Pangboche have collections of wood and dung, while only three of the fifteen have just wood. The ratio for houses is similar. One house has only wood and three have both wood and dung. While lodges in Pangboche use considerable electricity and kerosene for cooking, houses own only wood stoves for heating and cooking.

*PHERICHE*

As the last large settlement and the last stop for wood, Pheriche sits dramatically at over 14,300ft in the middle of a flat valley basin, bordered by the abruptly rising Himalayan peaks of nearly 7000 meters. The patterns of energy use in Pheriche are similar to those in Pangboche. The difference between the two places is that there is less use of wood, and more use of yak dung, kerosene, and electricity in Pheriche. At Friendship Lodge in Pheriche, yak dung is used to heat the eating room in the morning from 7:00am-10:00am, and in the evening from 4:00pm-9:00pm. Pots of water are heated on top of the stove while it is lit. The kitchen is almost as big as the eating room, and it doubles as the living space for the family there—a mother, father, two young girls and a grandmother. The small smoky kitchen stove uses a mixture of wood and dung. Though it is used primarily for heating the room, the stove is also used to heat water, and occasionally make a small breakfast. A large amount of the cooking is done on the two kerosene stoves, as well as on the two electric burners that are used with less frequency.

In Pheriche twelve of the seventeen lodges have both wood and dung collections. Three lodges have only dung, and two have only wood. Five out of eight houses have both wood and dung, three have only dung, and not a single house has only wood. Unlike villages down lower, many of the houses in Pheriche own and use Kerosene stoves for cooking.

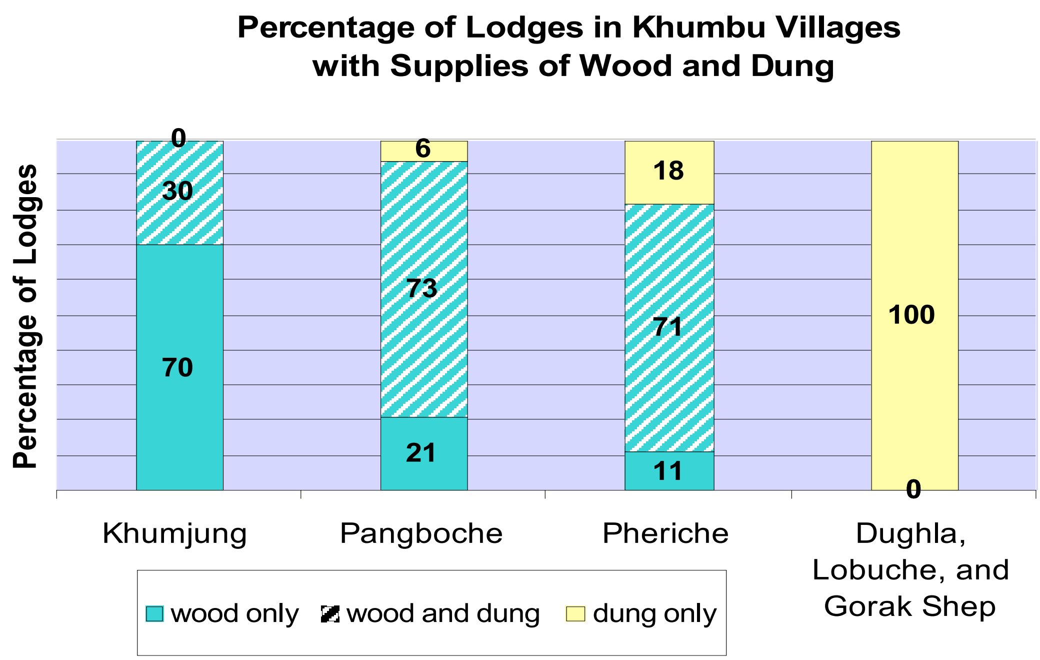
*ABOVE PHERICHE*

Above Pheriche are three more villages of smaller size. Two hours northeast from Pheriche is Dughla (4620 meters); another two hours up the hill is Lobuche (4900 meters); and the last two hour stretch brings you up to Gorak Shep (5160). None of these three villages burns wood for heating or cooking; there are no wood piles in any of them. The only sources of energy are kerosene, dung, and the sun. In Dughla, the one medium sized lodge uses only the two kerosene stoves for cooking, both of which are almost always on. The wood stove in the kitchen burns a steady stream of yak dung for heating. It is also used to heat water for washing dishes. The stove in the eating room uses dung for heating, both in the morning and in the evening.

Of the fourteen lodges in Lobuche and Gorak Shep, every single one has many massive walls of dried yak dung, which are used for heating in the eating rooms twice a day. Cooking all takes place on kerosene stoves. Many of the lodges, especially in Gorak Shep, don't have wood burning stoves in the kitchen. There are no electric burners because there are no hydro projects to supply the necessary electricity. At this high elevation, the few light bulbs are powered with small solar panels.

The information above describes the main sources of energy that are used in the Khumbu. It also illustrates how these sources are used, and the patterns of use between villages of lower and higher altitude. In general, wood and yak dung are key sources of energy for cooking, and they are the only sources available for heating. Kerosene and electricity also play very important roles.

Between the houses and lodges in villages of higher and lower elevation there is a clear pattern in the use of energy sources for heating and cooking. At lower elevations, in places like Benkar and Khumjung, wood is used regularly or exclusively for heating and cooking. As an exception to this, lodges and houses that receive electricity from Thame's hydro plant use electric burners (in addition to) frequently for cooking, especially in the summer. Higher up, in Pangboche and Pheriche, woodfuels are used little for cooking, and almost never for heating. In the eating room stove yak dung is used for heating, and in the kitchen stove it is used in combination with wood for heating and for minimal cooking. Kerosene and electricity are the major energy sources for cooking. Above Pheriche woodfuels disappear entirely, as do hydro projects that can supply enough energy for cooking. Yak dung is burned for heat, and kerosene is used for cooking. Throughout the Khumbu, electricity for lighting comes almost entirely from small solar panels on the roofs of houses and lodges. Lastly, houses in the Khumbu are a bit more reliant on biofuels than lodges.




**What explains the patterns of energy use, and why are biomass fuels the dominant source of energy?**

There are four central realities that each partially explain the patterns of energy in the Khumbu described above. These factors include government regulations on wood collection, preference of energy (price, convenience, etc), supply of energy, and existing infrastructures. The combination of these realities and explanations highlights why biofuels are the main source of energy. Ultimately what is illustrated is that people in the Khumbu are dependent on biofuels because of a lack of available alternative energy, as well as a lack of alternative heating infrastructures.

The government regulations on collecting wood have a huge effect on the price and accessibility of wood for villages in the Khumbu. They therefore explain the switch from the heavy use of wood around Khumjung, to the increased use of yak dung and kerosene at higher elevations.

It is common knowledge in the Khumbu that not much more than five years ago people were free to cut down trees 365 days out of the year from wherever they wanted. Except in the highest villages where trees simply don't grow, wood burning was virtually the only source of energy. Even trekking and climbing groups used to cheaply buy logs, and every night build their own small kitchens for burning wood to cook dinner. Since then regulations on collecting wood have drastically changed patterns of energy use.

In a single year there are only two fifteen-day periods during which lodges and houses can collect wood. The two periods are from May first to May fifteenth and from December first to December fifteenth. During these periods every house and lodge can have only two people collect wood. Each person can only take one load a day, which, depending on who is carrying the load, is usually about 30 kilos. Few people carry more than 40 kilos. Theoretically, then, the maximum amount of wood a lodge or house can collect in a year is about 1800-2400 kilos. If wood was used every day that would amount to only 4-6 kilos a day, which is certainly not enough for the winter trekking season when some lodges use as much as of 20 kilos a day. For most lodges, however, getting the maximum amount of wood is impossible. Considering that every house and lodge in every village collects wood during those thirty days, there is never enough labor for everyone to find two people to carry wood.

As the main organizer of energy supplies in the Khumbu, Tenzing from Hidden

Village Lodge has lists of all households and lodges in Khumjung, on which are the names of the people that are collecting for them during any given period. He uses these lists to distribute permission slips to the workers. The list for the collection in December 2007 showed that around a quarter of the houses and lodges had only one worker registered to carry wood. In addition to the shortages imposed by limited labor, shortages also arise from laborers inability to get full loads of wood. This is because wood for collection must already be dead, and the dead wood is very limited. The cutting down of live trees is prohibited.

Lastly, the villages examined in this study can only collect wood from two locations. One is a forested area above the village of Phunki Tenga, which is about an hours walk north of Khumjung, along the same trail that leads to Tengboche and Pangboche. The second area is just above Tengboche, right next to the first.

While each lodge and house is allowed a free quota of wood, these regulations greatly hinder people’s ability to get it. Compounding the access problem is the high price of labor due to the collection limits. On top of providing food and a place to stay, lodges pay especially high wages to the laborers given their shortage at the time. In brief, regulations mean that price and availability are two factors greatly limiting supplies of wood. Furthermore, because of the nature of the regulations, price and accessibility are much more problematic for villages farther away from collection areas.

In Phunki Tenga, right next to the collection area, one lodge owner I spoke to pays each laborer 150 rupees per load. In Khumjung, Tenzing pays 250 rupees per load, in Pangboche it's 500 rupees per load, and in Dughla it's 800. Also, the food that lodges have give their workers is significantly more expensive for lodges up higher. All told, a single 30 kilo load of wood costs well over 1000 rupees in Dughla. It is understandable, then, that the lodge in Dughla doesn't use wood at all. Even if it wanted to, however, wood is seldom available at that altitude.

Villages farther away from wood collection areas have rapidly diminishing access to wood. In Phunki Tenga, where the wood is collected, laborers have a short walk and can easily collect for fifteen days in a row. Workers from villages ten miles away cannot make round trips that many days in a row. Additionally, workers in villages close to the collection areas spend far fewer hours walking, and thus have many more hours to find the scarce dead wood. Workers coming all the way from Pheriche don't have enough time to find a full load of wood. Lastly, most lodges at higher elevations are closed for six months of the year and can only collect wood in December.

In summary, government regulations on wood collection create price and accessibility problems which mean that almost no lodge is able to get enough wood to meet all of its energy demand. Other energies such as dung, kerosene, and electricity are necessary supplements. More importantly, though, the shortages caused by the regulations explain the pattern of substituting yak dung and kerosene for wood, in villages farther away from collection areas. That is, the tendency for lodges to switch to using yak dung for heating, and kerosene for cooking as regulations make wood more expensive and inaccessible for villages at higher altitudes. This reality is an important piece of the explanation of why biofuels are needed as a source of energy, and especially for heating.

A further illustration of this dependence will come from looking at the other realities that govern the patterns of energy. One of these is the fact that electric and kerosene stoves are normally preferred over wood stoves for the purpose of cooking. At Hidden Village Lodge in Khumjung, Tenzing pays 6000 rupees a month for a supply of 4 kilowatts of electricity. Compared to the price of wood, using electricity is much cheaper. Additionally, wood stoves are slow to start and to heat, labor intensive, and smoky. And woodfuel collection, as was previously described, is time consuming, difficult, expensive, and unreliable. In contrast, the electric burners are quick and simple, need no maintenance, and require no labor to get fuel. In the summer when it's warm and the trekkers aren't around, lodges and houses with electric burners and access to electricity will use it as their only source of energy. “With more electricity,” Tenzing said, “everybody would use less wood.”

Although kerosene is more expensive than electricity, it also has many benefits over wood burning. Kerosene stoves require much less work to operate, the flame is much hotter, it burns cleaner, and compared to wood collection, getting kerosene from Kathmandu is a relatively simple process.

So if wood is expensive and difficult to obtain, and electric and kerosene stoves are preferred for cooking, why are biomass fuels used? There are two current limitations with electricity and kerosene that explain this. First, neither of these sources of energy can presently be used for heating. The only infrastructure that lodges and houses in the Khumbu have for heating is wood burning stoves. In the mornings, even though it would be cheaper and more practical for lodges in Khumjung and Pangboche to use only their electric burners, both use their wood burning stoves because of the need for heat. Slightly different from Khumjung lodges, however, Pangboche lodges use more yak dung for heating, and thus kerosene for cooking because wood is more expensive and difficult to get there.

For lodges and houses, the need to use wood and dung for their ability to heat is only half the explanation. As Tenzing explained so simply, "only five years ago everybody only had wood. Change must happen slowly, and right now there isn't enough electricity or kerosene." As a board member of the Khumbu Bijuli Committee, Tenzing has been trying for over a year to find funding to expand the current Thame hydro project by an additional 300kw. "Demand for electricity," he said, "is much greater than supply." Similarly, even though Kerosene can be easily purchased from Kathmandu, the supply in the Khumbu is very limited because there are not enough helicopters available to fly it in.

In summary, even though cooking with electric and kerosene burners is preferred to cooking with wood, there currently aren't utilities that can use electricity or kerosene for heating; furthermore, they are tremendously limited sources of energy. Thus, biomass fuels continue to be the main source of energy because of the lack of an electric or kerosene heating system, and also because there currently isn't enough electricity or kerosene to do substantial cooking or heating with. This was partially evidenced above by illustrating the effect that government regulations on wood collection have on energy patterns. That is, the tendency for lodges and houses to use wood for cooking and heating until price and accessibility force them to heat with dung, and cook with alternatives that would otherwise be widespread with a larger supply, and the ability to use them to heat.

**Implications for the Khumbu**

The case study above clearly illustrates the patterns of energy in the Khumbu, and the underlying forces which explain those patterns and the dependence on biomass fuels. The descriptions of the villages, lodges, and patterns of energy provide many important implications for designing energy projects in the Khumbu. For example, the study highlighted the regulations on wood in the Khumbu, the lack of roads, the surplus of sun, the affordability and preference of electric stoves, the construction and size of houses, and many other realities that must ultimately determine what a development project looks like. All of the findings in the case study should be used with future research as a guide in planning specific and locally appropriate methods for reducing the use of biomass fuels.

Here are just a few of the case study's major implications for how to reduce the use of biomass fuels. The first is to provide an alternative way or infrastructure for heating, one that can use energy from something other than burning biomass. This could be anything from electric heaters to passive or active solar heating systems. The second implication is to increase the amount of alternative energies that could—with the proper infrastructure—be used to heat and cook. One example is electricity. As was described in the literature review, the Khumbu has amazing potential in developing its hydropower resources. Also, the case study illustrated the success of existing hydro projects, as well as the preference for cooking with electricity when it is available. Future development of hydro power could provide even high altitude, remote villages with cheap and easy energy. This would generate a huge reduction in costs for houses and lodges given that the kerosene they currently use has to be carried in dozens of miles and up thousands of feet.

Hydroelectric developments could clearly provide the Khumbu with an abundant source of energy that could—with the proper infrastructure—be used for heating, and replace the use of woodfuels. Equally important, hydroelectricity could reverse the foreign exchange deficit that is spiraling out of control due to the importing of petroleum products. Not only would there be less demand for petroleum products, Pokharel (2001) suggests that large-scale hydro development projects should focus on exporting electricity to many other Asian countries. This could represent a significant source of earnings for Nepal.

A final suggestion is the use of conservation techniques, which, for an area where energy is so precious, are almost always the most cost effective and easiest way to increase the amount of available energy. For example, they could free up some of the valuable and limited electricity, or they could reduce the amount of wood that is required to heat buildings. Reducing the amount of energy that is required to heat a building also implies that a hard to come by alternative like electricity could more likely be used for heating if there is an appropriate infrastructure to do so.

Based on my observations there are two very simple conservation techniques that would reduce the amount of energy that is required to heat the buildings. First, the huge windows that allow the sun to warm a lodge during the day are also the greatest source of heat loss at night (Wyatt, Scott. Personal interview. 7 December 2007). The thin cloth curtains that cover the windows at night do almost nothing for insulation. Lodges would save enormous amounts of their limited and expensive energy by using simple, cheap, air tight shutters. Insulated shutters would be even more effective, and only slightly more expensive.

Another massive source of heat loss for Khumbu buildings are the ventilation systems for the kitchens' wood burning stoves. Currently heat is being dumped out of the buildings at night through the draft systems, which have an open hole in the roof. Very easily installed and cheap closing systems would greatly conserve the buildings' heat. The combination of both window shutters and stove ventilation closers could cut the amount of energy required for heating a building by upwards of half (Ibid). Reducing heat loss at night not only conserves the source of energy being used to heat (currently wood), but also it conserves the suns heat that is brought in during the day. These two simple techniques could save huge amounts of money, and greatly increase the amount of available energy by reducing what is needed to heat a house. Additionally, reducing the amount of energy it takes to heat a house means that it would be that much easier to use an alternative source for doing so.

As was explained above, lodges and houses currently heat their water using electrically heated metal coils. With clear skies for most of the year, however, the Khumbu has a perfect opportunity to take advantage of the sun for this purpose. As is being done with increasing frequency in other developing countries, large sheets of small black rubber tubes can be laid on the roofs of houses, and filled with water which is then heated by then sun. For areas that are cold at night there are small pumps that drain water out of tubes in the evening. This is an incredibly easy and inexpensive way to use the sun to heat water (Ibid). Furthermore, the storage tanks of hot water can be kept inside houses to provide heat; and the spacious Khumbu houses could easily accommodate the large tanks. Solar water heaters could provide abundant hot water and heating for buildings. In doing so it would also free up huge amounts of the Khumbu's precious electricity, much of which is currently used inefficiently to heat water.

With heating and additional electricity from the solar water heaters, the conservations techniques for retaining building heat, further hydropower developments, and an electrical heating system, lodges could significantly reduce, and eventually eliminate the burning of biomass fuels for energy.

Given the prospects for severe and irreversible damage to global climate change, the natural environment, and human wellbeing, preservation of the world's natural areas and processes may well be the most important issue of our time. The use of biomass fuels in most of the world's rural mountain villages is threatening the health of the natural world and the quality of life for millions of people. The patterns of energy, motivating factors, and explanations presented in this thesis have laid the ground work for future projects to significantly reduce the amount of biomass fuels being burned for energy in the Khumbu.

**Appendix A**


(Green Lotus Trekking)

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