Atsungiumajurniapaa, Nunavut
Latitude: 67° 06' 07 North: Longitude: 87° 18' 09 West
Time Zone: GMT-5 (1 hr behind EST) -

Atsungiumajurniapaa, Nunavut is a remote Inuit Community of about 200 people located just above the Arctic Circle in the Canadian North. It is regionally accessible only by airplane and sealift and only for the summer months of June to August. After arriving by boat or plane in Naujat (Repulse Bay), one must travel 100km northeast by snow- or dogsled to reach the community. Naujat is the closet community with an independent electricity generating facility, and its grid is unavailable for extension.

The people of Atsungiumajurniapaa live traditionally. They hunt seal, narwhal and caribou and herd reindeer. These are their main source of sustenance. The community has a herd of about 60 reindeer, which is actually unusual for a North-American Arctic community. A quick-flowing stream provides access to the bay from July to August, but quickly ices off at the beginning of October. During the winter months pack-ice makes traditional sea navigation impossible and hunters from the community typically hunt for seal at their airholes. Moreover since their village is located above the Arctic treeline, community members' intake of vegetables is limited to some of the edible scrub bushes, grasses and tubers that grow nearby in the summer months and to high-cost imported vegetables from the South. Tomatoes, for example, can cost over $15 US per kg.

The environment around Atsungiumajurniapaa is true arctic tundra; a vast plane on three sides and a protected bay on the fourth. Precipitation during the year is limited to only 10-20 mm of snow and drizzle, however a strong breeze constantly whips up loose snow almost year-round, giving the illusion that it is always snowing. From April to September, Atsungiumajurniapaa can see up to 22 hours of daylight per day, while from December to March it may see only 2 hours per day. Typical temperatures range from 8 to 10°C (46 to 50°F) in the summer to -40 to -45°C (-40 to –49°F) in the winter. These conditions should be considered when designing an appropriate energy program.

Quilliq Power, a crown corporation founded to provide independent generating capacity in Nunavut, has expressed interest in opening a small generating facility in Atsungiumajurniapaa, however it took several years for the last community promised a facility to receive one. Moreover, Quilliq Power can only promise a gasoline generator rated at 5 kW. Given the lighting and heating needs of the community, this may not be enough for the winter months.

However, there is currently one power generator in Atsungiumajurniapaa. It is a salvaged ski-sled engine that a local woman converted into a generator for the community building. Since it is so inefficient, it is only used in emergencies and is capable of generating 1200W (original rating was 3.7hp). Generally, though, the main source of heat and light is whale and seal blubber and oil. Any fuel that is imported from Naujat is used to power the generator or the 4 ski sleds, which are very important for hunting. In fact, most everything needed from the outside world, from electric parts to cooking utensils to foodstuffs, must be imported from Naujat at a premium. The cost for milk, for instance, can top $8 US/liter. Fuel, then, is also very expensive and can cost close to $5.75/liter. All items that travel to the Canadian North are extremely expensive, mostly due to transport costs.

The villagers' main source of income is the export of traditional crafts and music and adjustment payments given by the Canadian government for the diamond mine located within their community's traditional boundary. This money is generally pooled and directed towards collective needs by consensus decision. Their first priority, however, is food, warmth and fuel for hunting, which accounts for approximately 80% of the budget. The Inuit have little concept of "mine" and are very open to the idea of shared resources. As such, there is great potential for adoption of a community-based power solution if the right price can be reached. They envision electricity being used to provide heating and light in the main community building (which houses a shop and meeting hall), light personal houses and run a small yet-to-be-built medical clinic operating medical equipment.

Notes:

Some of the major organizations that could be approached as potential resources of capital support include

- The Canadian Government
- Quilliq Power

These are some of the *current* big players that may be relevant to energy access in this area. Development of independent generating nodes has been a high priority for Quilliq Power, you may want to access their website.

Choosing the appropriate types of energy for this area is very important to the success in improving access to energy and any subsequent economic development. The table on the following page may assist you in assessing options for energy sources. This is a partial list of potential components/services/prices that you may choose to use. If you find additional or more pertinent information, please use it and include the source from which you found it.

Not all information needed to present a strong report is contained in this document. More outside research (include sources and verify their reliability!) and careful consideration of conditions will be needed to make a strong assessment and design an appropriate system.

Selected Prices

Photovoltaic panels	US$700	$50W_p$
	US$850	$60W_p$
	US$1,025	$70W_p$
	US$1,300	$75W_p$
	US$1,700	$80W_p$
	US$2,100	$120W_p$
Inverters	US$250	300W
	US$276	500W
Batteries		
	US$95	Deep discharge, 100Ah/12v
	US$200	Deep discharge, 210Ah/12v
	US$975	Deep discharge, 400Ah/12v
	US$3180	Deep discharge, 1650Ah/12v
Generator	US$9,500	1000W
Gasoline	US$5.75/L	All fuel must be imported to Naujat and transported to Atsungiumajurniapaa.
Wind Turbines	US$2,500	Efficiency = 40%
Wind speed	6.6-8.0 m/s	The Arctic tundra can see some very strong winds, however they are very cold and constantly full of snow except for July and August.
Minimum wage in Nunavut	US$8.50/day	In Atsungiumajurniapaa only 26 people are employed at this wage, all are employees of a government weather station in Naujat. The rest both sell and export traditional crafts or perform necessary duties around the village and are not wage-employed. Adjustment payments from the government for the diamond mine amount to about $530/month.

Nyaja Chiefdom, Zambia
Latitude: 14º 8' South Longitude: 30º 50' East
Time Zone: GMT+1 (6 hrs ahead of EST) -

Nyaja Chiefdom is a remote rural area in the Nyimba district of the Eastern Province of Zambia. Nyimba is the closest city with grid electricity, but it is 60km away and requires a 4-wheel drive vehicle to manage the rough road. The next closest city is Petauke, which is about 79km away. Diesel, batteries, or kerosene can be bought from one of these two towns, and usually traders sell them in Nyaja for a higher cost.

In Nyaja, 43 villages are divided into 5 sections, with the furthest section being about a 1.5 hour walk from the chief's compound. Each village is composed of family groups of six to ten people. Most villagers are subsistence farmers who cultivate primarily maize for their family's consumption. The plot size varies from 0.25 to 1 hectare of land per family. Most families do not own any livestock, but those that do, only own a few chickens or goats which are allowed to roam freely around the village. There are 250 households in an area of 50,000 hectares, so families do not always border each other. Much of the area around the river is a flood plain. During each annual rainy season, the average total rainfall is 950mm. A stream divides one of the five sections from the rest, and is not passable by foot in the rainy season. The Mvuvye river also isolates Nyaja Chiefdom from nearby cities during the rainy season. Most villages have easy access to water, but these surface water sources run dry during the dry season.

There are currently no electricity generators in Nyaja. The Chief has one diesel-powered grain mill, for which villagers pay a fee to use. The Nyimba District Health office supplies the kerosene to power the vaccine refrigerator at the clinic. There are four PV systems in Nyaja, which are owned by the Chief, the clinic nurse, a successful store-owner, and the school. The average family cooks on a three stone wood or charcoal fire, uses candles for light at night, and buys batteries for flashlights or radios. Grid-distributed electric power is unlikely to be accessible in the region for at least one or two decades. Power from the grid is generated from one of Zambia's many hydroelectric dams. The nearest grid electricity is currently about 60 km away. Electricity would be used primarily for lighting and radios. A battery charging station might be feasible if people had access to car batteries.

When considering a system for this community, it is important to consider the capital resources of the community. Few people in this area have formal employment; most are subsistence farmers, some bake buns, a couple people have small stores or bars that sell necessities and serve as a social gathering place. As such, most villagers only have very small quantities of cash, and only a few of the wealthier or professionally employed villagers, like the clinic nurse, save large sums of money. Typically, to buy something of high value, one can take out informal loans from relatives or some of the wealthier villagers for as high an interest rate as 50%. Recently, the concept of group lending was introduced to provide a means for women to save money and generate income by lending money to others. A group of women contribute a small amount each week to a group fund that can be lent to other villagers who pay it back with interest.

Some of the major organizations that could be approached as potential resources of capital support include

- Basic Education Sub-Sector Investment Programme
- PVESCO (Photo-Voltaic Energy Service Company) program
- Microfinance institutions may be an option, if the energy is being used to generate income.

These are some of the *current* big players that may be relevant to energy access in this area. Development of the interior and rural areas has in theory been a high priority for the state and federal governments in Zambia, however in practice, remote villages like Nyaja have not benefited from these programs.

Choosing the appropriate types of energy for this area is very important to the success in improving access to energy and any subsequent economic development. The table on the following page may assist you in assessing options for energy sources.

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Table 1 Selected Prices

Photovoltaic panels	US$250	$50W_p$
	US$320	$60W_p$
	US$376	$70W_p$
	US$450	$75W_p$
	US$460	$80W_p$
	US$610	$120W_p$
Inverters	US$100	300W
	US$200	500W
Batteries		
	US$145	Deep discharge, 100Ah/12v
	US$320	Deep discharge, 210Ah/12v
	US$900	Deep discharge, 400Ah/12v
Generator (diesel)	US$1100	1000W
Diesel	US$1.53/L	Diesel costs less in Lusaka, and more as you travel further from the capital.
	US$2.47/L	In Nyaja, the diesel is sold by store owners who make more than 50% profit.
Bricks		Many villagers in Nyaja know how to make traditional fired clay bricks from local soil so they do not buy commercial bricks.
Wind speed	1.9m/s to 4.2m/s	There are some places in Zambia that have winds greater than 5m/s, but Nyaja is not one of them.
Mean wage in Zambia	< US$2/day	Most people in Zambia live on less than $1/day. There is about a 50% unemployment rate. Most villagers are subsistence farmers so they have little cash income.

Boipelego Village, Phamong, Lesotho
Latitude: 29º 22'S Longitude: 29º 02'E
Time Zone: GMT +2

The Phamong region is home to several small farming communities which cluster around the water of the wide, muddy Senqu River. Boipelogo is one of the more developed villages, with a large church that attracts Christians for worship from several neighboring communities on Sundays. There is also a technical centre, the Boipelego Business and Community Development Centre. While this school is currently self-sufficient in energy through the use of solar panels, continued expansion is planned, so additional power at the school will be required. There is also a clinic, two small stores which each have a large meat-storing refrigerator, and a public elementary school which educates about one hundred kids annually. In the village, there are around 100 families, each with about six to ten members. Most of the men work the soybean and maize fields during the day, with families working on large, multi-acre community plots rather than smaller fields. The terrain is harsh and dry, with cracked gullies running across the landscape as a result of massive erosion. The typical home has a small radio, a few 10W light bulbs, and perhaps a black and white television. The radios are usually on for most of the day, with the lights running for five or six hours at night and the TV used only for a couple of hours each night. Cooking is done using biomass, and most women spend two to three hours per day collecting wood to burn. While power was supplied by a diesel generator in the village to about half the homes, recent increases in the price of diesel of nearly 25% (Current price = 7 Rand (ZAR) per liter) have made this a costly option.

There are other resources available in the area. Solar radiation is high, with over 300 days of sun a year. However, solar panels are expensive to use, as they have to be imported from South Africa. Panels cost about 4US$/watt, and there have been problems with theft. Any type of 12V battery can be purchased for around 50US$ in Johannesburg, about a five hour drive away. There are no local recharging stations, but the batteries can be brought to Mohale's Hoek for a recharge (2 hrs away). Inverters can also be purchased in Johannesburg for around 60US$. Locally, the Senqu River is another potential source of power. High-flow micro-hydro turbines, such as the Francis or Kaplan (efficiencies around 90%), can be purchased for around US$2,000 and brought to Boipelego from Lesotho. The river has a flow of $5m^3/s$ in the summer, but flow varies tremendously. In the winter, the flow is around $2m^3/s$, and rainstorms (Common from December to February) can increase flow to almost $7m^3/s$. The river is about 100m wide, though the seasonal variation in flow means that the actual height varies from 1m to 3m. Any bank-mounted installed turbine would have to factor in some downtime for when the height of the river or amount of flow was outside operating parameters. Wind power is also an option, though the variation is rather high. Wind turbines can be bought in Johannesburg for around US$800 (efficiencies around 40%), or they could be constructed of locally available materials like fiberglass and wood for a slightly lower cost (but also a lower efficiency of around 30%). Speeds of 5m/s to 10m/s can be found consistently at the tops of some nearby peaks, but their distance from Boipelego is 1km to 2km.

Grid electricity is not widespread in Lesotho, and only about 10% of rural locations are electrified. Boipelego is about two hours from Mohale's Hoek (which does have grid connection) along a dirt road, and the closest village with electrification is located on the other side of the Senqu. Diesel and liquefied natural gas are available but are costly, and transportation is a major issue for the community. As for technical skills, the students at the technical centre are skilled in welding, and some could be hired to maintain the generation scheme for a relatively low cost (10% greater than the average per capita income in Lesotho).

Loans are available from the government for some electrification projects, but interest rates are high (nearly 40%). The people do not have many assets that could be used as collateral; instead, most of their income tends to come from working in the South African mines and gets spent for food or other immediate needs.

Some of the major organizations that could be approached as potential resources of capital support include

- Appropriate Technology Services, a Maseru-based government organization that works in disseminating appropriate technology for rural communities. They have partnered with D-Lab in the past (More information can be found about ATS at http://web.mit.edu/ats)
- World Bank, as they are currently funding a project on parabolic solar troughs that are used as solar thermal power generators. This project was started by an MIT student who actually led the D-Lab Lesotho trip for the past two years (http://www.synergeticpower.org/).

These are some of the *current* big players that may be relevant to energy access in this area. Development of the interior and rural areas has always been a high priority for the government of Lesotho, and energy access is one of the key factors in economic development.

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Assentamento Pirarucu, Tocantins, Brazil
Latitude: -11º 48' Longitude: -49º 28'
Time Zone: GMT -3

The Assentamento Pirarucu is in rural Tocantins, Brazil, near the Rio Javaé. In Assentamento Pirarucu, family groups of six to ten people live on acres of otherwise isolated land. Each family owns approximately 75 hectares of land. The families all have livestock (a typical family may have 6 cows, 4 pigs and some chickens), and cultivate plants like corn and cassava (approximately 1 hectare). Other plants like grasses, palm, mango, papaya, and banana grow everywhere they are allowed. There are 150 households in an area of 24,000 hectares, so families do not always border each other; there are wetlands, roads, and densely forested areas between family lands. About 10 km from the settlement flows the Rio Javaé; the closest families live about 5 km from the river, the furthest are about 15 km away. The river runs through a wide basin, about 500 meters wide, and has seasonal variations in flow rate with rates of 10 $L/s/km^2$ in the rainy season (November to April) and 2 $L/s/km^2$ in the dry season.

Generators are not uncommon now. Families that have a generator typically use it to power a couple overhead incandescent lights, a refrigerator, a fan, and a television. Grid-distributed electric power is slowly becoming accessible in the region, and should be available in the Assentamento Pirarucu within five years. Power from this grid is from one of Brazil's large hydroelectric dams. The nearest grid electricity is currently about 50 kilometers away.

When considering a system for this community, it is important to consider the capital resources of the community. Few people in this area have what would be considered typical jobs in the US; most are subsistence farmers, some make crafts, a couple people have "stores" or "bars" that sell necessities and serve as a social gathering place. As such, cash (the real, plural reais) is only available in very small quantities, and saving and investment in money is unheard of. Typically, if one wants to buy something of high value, the first step to buying it is to sell a cow or other animal. Financial strategies like loans are hindered by high interest rates, which, though they have fallen in recent years, are still around 10%.

Some of the major organizations that could be approached as potential resources of capital support include

- The Instituto Nacional de Colonização e Reforma Agrária, which formed the settlements more than ten years ago when the FUNAI (Indigenous Affairs Bureau) established an indigenous reservation nearby
- The Fundação Bradesco, a national non-profit which runs a working farm and boarding school for children that live in the area villages, settlements, and small

towns. The school in Canuanã, near the Assentamento Pirarucu, is a D-Lab partner in Brazil.

- The Instituto de Desenvolvimento Rural do Estado do Tocantins, the rural development agency of the government of the state of Tocantins

These are some of the *current* big players that may be relevant to energy access in this area. Development of the interior and rural areas has always been a high priority for the state and federal governments in Brazil, and energy access is one of the key factors in economic development.

Choosing the appropriate types of energy for this area is very important to the success in improving access to energy and any subsequent economic development. The table on the following page may assist you in assessing options for energy sources.

Not all information needed to present a strong report is necessarily contained in this document. More outside research (include sources and verify their reliability!) and careful consideration of conditions will be needed to make a strong assessment and design an appropriate system.

Table 1 Selected Prices

Photovoltaic panels *Painéis Solares*	US$4.85/$W_p$	
Inverters *Inversores*	US$100 US$215 US$360 US$575 US$720 US$1080	150W 300W 500W 800W 1000W 1500W
Batteries *Baterias*	US$40 US$65 US$110 US$145	Deep discharge, 40Ah Deep discharge, 70Ah Deep discharge, 115Ah Deep discharge, 150Ah
Generator (diesel) *Gerador*	US$1520 US$1320	6.7 HP, 3.5 Kva max. 1.8 Kva max.
Diesel *Diesel*	US$1.59/L	Brazil has a strong policy for biodiesel. B2 will be mandatory in 2008.
Bricks *Tijolo*	US$1.20/10	Many families have their own bricks already, which were donated by the government to be used for building new houses. However, the tijolo houses are too hot, so most people did not build with them and have a pile somewhere on their land.
Wind speed *Potencial Eólico*	3.5 m/s 3.5 m/s 6 m/s 5 m/s	December-February March-May June-August September-November
Mean wage, within formal sector in N. region *Salario medio*	US$6/hr	Brazil has a strong informal sector, and currently, few people living in Pirarucu have access to formal sector jobs
Wind turbine *Turbina eólica*	\$1500/kW_e	Installed cost per kilowatt
Micro-hydro *Micro-hidroeléctrico*	\$4000/kW_e	Installed cost per kilowatt

Dikgomo, Ghanzi District, Botswana
Latitude: -21º 45’ Longitude: 20º 5’
Time Zone: GMT +2

Dikgomo is a small village in western Botswana in the Kalahari Desert near the border with Namibia. The land surrounding Dikgomo is primarily small cattle posts, where families keep their cattle. The landscape is primarily desert scrub. Most of the land is tribal grazing land, without clear ownership, but there are a few private farms about 15 km from the village. There are three times as many cattle as people, and twice as many goats as cattle. The cattle are kept at the cattle posts, where they are allowed to freely roam and graze; the goats are dispersed throughout the cattle posts and the village. There are no permanent surface water sources—water in the village is provided through five government-installed boreholes that reach into a water table approximately 100 m below the surface. Some of the private farms have wind-powered pumps to supply their cattle with water. The seasonal rains, if they come, arrive in December and fall sporadically until mid-February. If the rains are good, the desert becomes a grassland; if not, only the acacia shrubs show signs of greenery. During the rainy season, water accumulates in large puddles called pans; these often last a few months into the dry season, but rarely until the beginning of the next rainy season. When the rains are especially heavy, the roads become impassable and take up to a week to dry out. The village is about 700 km from the capital, Gaborone, the first 200 km is paved, the rest is a poorly maintained track. Transport of supplies into the village is both difficult and expensive, as only the most rugged items survive the journey intact.

Crops are not grown extensively in the area, though there are some plots of maize, it is not uncommon for the crop to fail due to drought. When this does happen, the government drought relief program provides bags of “mealie meal” which the villagers use to make a thick porridge to eat with the meat. Few vegetables are grown, but during the rainy season, there are many wild plants that grow in the bush that can be harvested and consumed.

There are 70 households concentrated in the village each comprised of several rondavels that make up the family compound. Children from these families attend the Dikgomo primary school; those that pass their primary leaving exam join students from five surrounding villages to attend the Kgalagadi Community Secondary School, which is also located in the village. The government pays for the school to provide tea and bread to the students during the morning break, and also a hot meal at lunch. Traditionally, food is cooked in three-legged pots over a wood fire. Wood has become scarce in the area surrounding the village and is often brought to the school using the headmaster’s pick-up truck. Sometimes, the meal program must be suspended due to a lack of cooking fuel.

None of the households have electricity, except the headmaster, who has a small diesel generator. Light is produced by kerosene lanterns or candles. Few of the adults in the village have a formal education, and although there is an interest in adult education programs, they have been difficult to sustain, due to the lack of lighting at the school. There is a new clinic that has been built on the edge of the village, and the government has stationed a nurse at the site, however the services are quite limited, due to the lack of equipment. The closest grid electricity is in the mining town of Jwaneng, about 500 km away.

When considering a system for this community, it is important to consider the capital resources of the community. Livestock is the traditional measure of wealth, and most people would rather invest in a cow than a bank. As such, cash (the *pula*, which is setswana for “rain”) is only available in very small quantities, and saving and investment in money is rare. Bank loans are available at a 15% interest rate, though few people apply for them. Typically, if one wants to buy something of high value, the first step to buying it is to sell a cow or a goat. The Botswana Meat Commission provides a high price for livestock, as part of a European Union aid package, though transport to the abattoir takes about 10% of the profits. Few people in this area have formal employment; some make crafts, a couple people have small stores or bars that sell necessities and serve as a social gathering place. There is currently a government initiative to promote micro-enterprise, and several indigenous plants have been identified as having a high value on the tourist market. Although low interest loans (5%) are available as part of this initiative, no groups have formed to take advantage of them, due to the difficulties in drying and packaging the plants. The sealing equipment for packaging the teas and dried fruit, though relatively inexpensive, requires electricity to operate.

Historically, development priorities have targeted educational initiatives; electrification of rural areas has not been a high priority. Recently, however, the government has recognized the importance of infrastructure to economic development and has shifted some of its resources to rural electrification schemes. The government of Botswana now offers a 500 pula subsidy for people interested in installing photo-voltaic systems in rural areas. The table on the following page may assist you in assessing options for energy systems.

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Table 1 Selected Prices and Information

Photovoltaic panels	US$380	$50W_p$
	US$416	$70W_p$
	US$520	$80W_p$
	US$770	$120W_p$
Inverters	US$210	300W
	US$320	500W
Batteries		
	US$125	Deep discharge, 100Ah/12v
	US$240	Deep discharge, 210Ah/12v
	US$400	Deep discharge, 400Ah/12v
Generator (diesel)	US$1500	1000W
Diesel	US$3.15/L	In Dikgomo, the diesel is sold by store owners who make more than 50% profit.
Bricks	US$0.25 each	Cement bricks are made in the village using a ram press. There is not sufficient fuel to make fired clay bricks.
Wind speed	3.2m/s to 5.4m/s	
Wind turbine	US$1500/$kW_e$	Installed cost per kilowatt
Mean wage in Dikgomo	US$3/day	The average wage in Botswana is about $5/day, however in rural areas such as Dikgomo, the wage is significantly less.

Diphudi, Ghanzi District, Botswana
Latitude: -21º 45' Longitude: 20º 5'
Time Zone: GMT +2

Diphudi is a small village in western Botswana in the Kalahari Desert near the border with Namibia. The land surrounding Diphudi is primarily small cattle posts, where families keep their cattle. The landscape is primarily desert scrub. Most of the land is tribal grazing land, without clear ownership, but there are a few private farms about 15 km from the village. There are three times as many cattle as people, and twice as many goats as cattle. The cattle are kept at the cattle posts, where they are allowed to freely roam and graze; the goats are dispersed throughout the cattle posts and the village. There are no permanent surface water sources—water in the village is provided through five government-installed boreholes that reach into a water table approximately 100 m below the surface. Some of the private farms have wind-powered pumps to supply their cattle with water. The seasonal rains, if they come, arrive in December and fall sporadically until mid-February. If the rains are good, the desert becomes a grassland; if not, only the acacia shrubs show signs of greenery. During the rainy season, water accumulates in large puddles called pans; these often last a few months into the dry season, but rarely until the beginning of the next rainy season. When the rains are especially heavy, the roads become impassable and take up to a week to dry out. The village is about 700 km from the capital, Gaborone, the first 200 km is paved, the rest is a poorly maintained track. Transport of supplies into the village is both difficult and expensive, as only the most rugged items survive the journey intact.

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There are 70 households concentrated in the village each comprised of several rondavels that make up the family compound. Children from these families attend the Diphudi primary school; those that pass their primary leaving exam join students from five surrounding villages to attend the Kgalagadi Community Secondary School, which is also located in the village. The government pays for the school to provide tea and bread to the students during the morning break, and also a hot meal at lunch. Traditionally, food is cooked in three-legged pots over a wood fire. Wood has become scarce in the area surrounding the village and is often brought to the school using the headmaster's pick-up truck. Sometimes, the meal program must be suspended due to a lack of cooking fuel.

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Not all information needed to present a strong report is necessarily contained in this document. More outside research (include sources and verify their reliability!) and careful consideration of conditions will be needed to make a strong assessment and design an appropriate system.

Table 1 Selected Prices and Information

Photovoltaic panels	US$380	$50W_p$
	US$416	$70W_p$
	US$520	$80W_p$
	US$770	$120W_p$
Inverters	US$210	300W
	US$320	500W
Batteries		
	US$125	Deep discharge, 100Ah/12v
	US$240	Deep discharge, 210Ah/12v
	US$400	Deep discharge, 400Ah/12v
Generator (diesel)	US$1500	1000W
Diesel	US$3.15/L	In Diphudi, the diesel is sold by store owners who make more than 50% profit.
Bricks	US$0.25 each	Cement bricks are made in the village using a ram press. There is not sufficient fuel to make fired clay bricks.
Wind speed	3.2m/s to 5.4m/s	
Wind turbine	US$1500/$kW_e$	Installed cost per kilowatt
Mean wage in Dikgomo	US$3/day	The average wage in Botswana is about $5/day, however in rural areas such as Diphudi, the wage is significantly less.

Vumba Chiefdom, Zambia
Latitude: 14º 8' South Longitude: 30º 50' East
Time Zone: GMT+1 (6 hrs ahead of EST) -

Vumba Chiefdom is a remote rural area in the Nyimba district of the Eastern Province of Zambia. Nyimba is the closest city with grid electricity, but it is 60km away and requires a 4-wheel drive vehicle to manage the rough road. The next closest city is Petauke, which is about 79km away. Diesel, batteries, or kerosene can be bought from one of these two towns, and usually traders sell them in Vumba for a higher cost.

In Vumba, 43 villages are divided into 5 sections, with the furthest section being about a 1.5 hour walk from the chief's compound. Each village is composed of family groups of six to ten people. Most villagers are subsistence farmers who cultivate primarily maize for their family's consumption. The plot size varies from 0.25 to 1 hectare of land per family. Most families do not own any livestock, but those that do, only own a few chickens or goats which are allowed to roam freely around the village. There are 250 households in an area of 50,000 hectares, so families do not always border each other. Much of the area around the river is a flood plain. During each annual rainy season, the average total rainfall is 950mm. A stream divides one of the five sections from the rest, and is not passable by foot in the rainy season. The Mvuvye river also isolates Vumba Chiefdom from nearby cities during the rainy season. Most villages have easy access to water, but these surface water sources run dry during the dry season.

There are currently no electricity generators in Vumba. The Chief has one diesel-powered grain mill, for which villagers pay a fee to use. The Nyimba District Health office supplies the kerosene to power the vaccine refrigerator at the clinic. There are four PV systems in Vumba, which are owned by the Chief, the clinic nurse, a successful store-owner, and the school. The average family cooks on a three stone wood or charcoal fire, uses candles for light at night, and buys batteries for flashlights or radios. Grid-distributed electric power is unlikely to be accessible in the region for at least one or two decades. Power from the grid is generated from one of Zambia's many hydroelectric dams. The nearest grid electricity is currently about 60 km away. Electricity would be used primarily for lighting and radios. A battery charging station might be feasible if people had access to car batteries.

When considering a system for this community, it is important to consider the capital resources of the community. Few people in this area have formal employment; most are subsistence farmers, some bake buns, a couple people have small stores or bars that sell necessities and serve as a social gathering place. As such, most villagers only have very small quantities of cash, and only a few of the wealthier or professionally employed villagers, like the clinic nurse, save large sums of money. Typically, to buy something of high value, one can take out informal loans from relatives or some of the wealthier villagers for as high an interest rate as 50%. Recently, the concept of group lending was introduced to provide a means for women to save money and generate income by lending money to others. A group of women contribute a small amount each week to a group fund that can be lent to other villagers who pay it back with interest.

Some of the major organizations that could be approached as potential resources of capital support include

- Basic Education Sub-Sector Investment Programme
- PVESCO (Photo-Voltaic Energy Service Company) program
- Microfinance institutions may be an option, if the energy is being used to generate income.

These are some of the *current* big players that may be relevant to energy access in this area. Development of the interior and rural areas has in theory been a high priority for the state and federal governments in Zambia, however in practice, remote villages like Vumba have not benefited from these programs.

Choosing the appropriate types of energy for this area is very important to the success in improving access to energy and any subsequent economic development. The table on the following page may assist you in assessing options for energy sources.

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Table 1 Selected Prices

Photovoltaic panels	US$250	$50W_p$
	US$320	$60W_p$
	US$376	$70W_p$
	US$450	$75W_p$
	US$460	$80W_p$
	US$610	$120W_p$
Inverters	US$100	300W
	US$200	500W
Batteries		
	US$145	Deep discharge, 100Ah/12v
	US$320	Deep discharge, 210Ah/12v
	US$900	Deep discharge, 400Ah/12v
Generator (diesel)	US$1100	1000W
Diesel	US$1.53/L	Diesel costs less in Lusaka, and more as you travel further from the capital.
	US$2.47/L	In Vumba, the diesel is sold by store owners who make more than 50% profit.
Bricks		Many villagers in Vumba know how to make traditional fired clay bricks from local soil so they do not buy commercial bricks.
Wind speed	1.9m/s to 4.2m/s	There are some places in Zambia that have winds greater than 5m/s, but Vumba is not one of them.
Mean wage in Zambia	< US$2/day	Most people in Zambia live on less than $1/day. There is about a 50% unemployment rate. Most villagers are subsistence farmers so they have little cash income.

Boipuso Village, Phamong, Lesotho
Latitude: 29º 22'S Longitude: 29º 02'E
Time Zone: GMT +2

The Phamong region is home to several small farming communities which cluster around the water of the wide, muddy Senqu River. Boipuso is one of the more developed villages, with a large church that attracts Christians for worship from several neighboring communities on Sundays. There is also a technical centre, the Boipuso Business and Community Development Centre. While this school is currently self-sufficient in energy through the use of solar panels, continued expansion is planned, so additional power at the school will be required. There is also a clinic, two small stores which each have a large meat-storing refrigerator, and a public elementary school which educates about one hundred kids annually. In the village, there are around 100 families, each with about six to ten members. Most of the men work the soybean and maize fields during the day, with families working on large, multi-acre community plots rather than smaller fields. The terrain is harsh and dry, with cracked gullies running across the landscape as a result of massive erosion. The typical home has a small radio, a few 10W light bulbs, and perhaps a black and white television. The radios are usually on for most of the day, with the lights running for five or six hours at night and the TV used only for a couple of hours each night. Cooking is done using biomass, and most women spend two to three hours per day collecting wood to burn. While power was supplied by a diesel generator in the village to about half the homes, recent increases in the price of diesel of nearly 25% (Current price = 7 Rand (ZAR) per liter) have made this a costly option.

There are other resources available in the area. Solar radiation is high, with over 300 days of sun a year. However, solar panels are expensive to use, as they have to be imported from South Africa. Panels cost about 4US$/watt, and there have been problems with theft. Any type of 12V battery can be purchased for around 50US$ in Johannesburg, about a five hour drive away. There are no local recharging stations, but the batteries can be brought to Mohale's Hoek for a recharge (2 hrs away). Inverters can also be purchased in Johannesburg for around 60US$. Locally, the Senqu River is another potential source of power. High-flow micro-hydro turbines, such as the Francis or Kaplan (efficiencies around 90%), can be purchased for around US$2,000 and brought to Boipuso from Lesotho. The river has a flow of $5m^3/s$ in the summer, but flow varies tremendously. In the winter, the flow is around $2m^3/s$, and rainstorms (Common from December to February) can increase flow to almost $7m^3/s$. The river is about 100m wide, though the seasonal variation in flow means that the actual height varies from 1m to 3m. Any bank-mounted installed turbine would have to factor in some downtime for when the height of the river or amount of flow was outside operating parameters. Wind power is also an option, though the variation is rather high. Wind turbines can be bought in Johannesburg for around US$800 (efficiencies around 40%), or they could be constructed of locally available materials like fiberglass and wood for a slightly lower cost (but also a lower efficiency of around 30%). Speeds of 5m/s to 10m/s can be found consistently at the tops of some nearby peaks, but their distance from Boipuso is 1km to 2km.

Grid electricity is not widespread in Lesotho, and only about 10% of rural locations are electrified. Boipuso is about two hours from Mohale's Hoek (which does have grid connection) along a dirt road, and the closest village with electrification is located on the other side of the Senqu. Diesel and liquefied natural gas are available but are costly, and transportation is a major issue for the community. As for technical skills, the students at the technical centre are skilled in welding, and some could be hired to maintain the generation scheme for a relatively low cost (10% greater than the average per capita income in Lesotho).

Loans are available from the government for some electrification projects, but interest rates are high (nearly 40%). The people do not have many assets that could be used as collateral; instead, most of their income tends to come from working in the South African mines and gets spent for food or other immediate needs.

Some of the major organizations that could be approached as potential resources of capital support include

- Appropriate Technology Services, a Maseru-based government organization that works in disseminating appropriate technology for rural communities. They have partnered with D-Lab in the past (More information can be found about ATS at http://web.mit.edu/ats)
- World Bank, as they are currently funding a project on parabolic solar troughs that are used as solar thermal power generators. This project was started by an MIT student who actually led the D-Lab Lesotho trip for the past two years (http://www.synergeticpower.org/).

These are some of the *current* big players that may be relevant to energy access in this area. Development of the interior and rural areas has always been a high priority for the government of Lesotho, and energy access is one of the key factors in economic development.

Not all information needed to present a strong report is necessarily contained in this document. More outside research (include sources and verify their reliability!) and careful consideration of conditions will be needed to make a strong assessment and design an appropriate system.

Preak Russei, Kaoh Thum District, Kandal Province, Cambodia
Latitude: 11º 33’N Longitude: 104º 60’E
Time Zone: GMT +7

Preak Russei is a village of about 500 households located 5 hours north of Phnom Penh, the capital of Cambodia. The closest town with an electrical grid is in the neighboring district of Kien Svay, which is over 3 hours away with a river crossing. There has been a government initiative to extend power lines into Kaoh Thum since last year, but transportation of the necessary supplies and workforce is challenging due to the distance and geography. As a result, construction has not begun and spools of power cables are still sitting in a town near the borders of the Kien Svay and Kaoh Thum districts.

Most households in Preak Russei use kerosene or candles for lighting, though a few wealthier households have access to car batteries for powering lamps or even small television sets. Four years ago, the head of the village development committee purchased a small diesel generator and his sons now run a small enterprise that charges batteries for a small fee. Households with batteries report spending approximately $5 a month on charging services, walking up to 3 km to charge their batteries a couple times each week.

Preak Russei is primarily a farming community, with rice being the main crop. Many households also raise livestock such as chickens, goats, pigs and a cow or two for farming help and supply of milk. Biomass is typically used for cooking, but some of the more prosperous households use canisters of natural gas which are trucked in from town and ferried across the river on a motorized wooden raft. The river running along Preak Russei has a very languorous flow that diminishes in the dry season, but there are some wind resources available and the region receives over 300 days of sun.

The commune council and village development committee have been working together to build community latrines and expand the primary school. There has been political pressure to install a couple CFL or LED lamps at the school so children of less prosperous families may have a place to do homework at night. Another ongoing community project is a center to provide safe drinking water, designed and built by a local NGO called Resource Development International Cambodia (RDIC) in 2007. RDIC has recently started investigating the possibility of installing a small photovoltaic panel to provide electricity for the water treatment equipment. A 12V car battery is currently being used for powering the arsenic removal system* and the UV disinfection system, as well as charging cell phones in the village for a nominal fee. Proceeds from the sale of clean water ($0.03 for 10 liters, usually sold in a bottle) and charging services go towards maintaining the water center.

Loans are available from the government for some domestic electrification projects, but interest rates are high (nearly 35%) and the commune council would need to apply as the program is not open to single households. Most households, with the exception of the village head and other prosperous families, do not have many assets that could be used as collateral. Most families receive their income from farming or children working in Phnom Penh and spend it on food or other immediate needs. Though villagers in Preak Russei do not typically have a lot of cash on hand, there is a precedent of people being motivated to invest in infrastructure improvements. Last summer, some families managed to save enough to install pipes connecting their homes to the local water treatment center designed by RDIC.

Some of the major organizations that could be approached as potential resources of capital support include

- Resource Development International Cambodia (RDIC), a local NGO that operates in the Kandal Province (http://www.rdic.org)
- 1001 Fontaines, a French NGO that has started several solar-powered UV water treatment centers run by local entrepreneurs (http://www.1001fontaines.com/)
- Ministry of Rural Development, a program of the Cambodian government

These are some of the *current* big players that may be relevant to energy access in this area. Development of the interior and rural areas has been a high priority for the government of Cambodia, and energy access is one of the key factors in economic development.

Not all information needed to present a strong report is necessarily contained in this document. More outside research (include sources and verify their reliability!) and careful consideration of conditions will be needed to make a strong assessment and design an appropriate system.

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* Arsenic contamination in groundwater is a major concern for Preak Russei and other villages situated in the lower Mekong river basin. It has been referred to as the worst case of mass poisoning in human history, affecting an estimated 2 million in Cambodia and 140 million worldwide. Naturally occurring arsenic is called a silent killer because the chemical is colorless, odorless and tasteless. Exposure to high concentrations of arsenic over a prolonged period of time can cause disease like arsenicosis, in which the affected person develops lesions on the hands and feet that make it painful to walk and work. Ultimately, accumulation of arsenic in the body can lead to organ failure and death. Ground wells in Preak Russei have been shown to have arsenic concentrations as high as 1000-2000 ppb, while the World Health Organization standards for drinking water are 5 ppb.

Table 1 Selected Prices and Information

Photovoltaic panel	US$0.50/kWh	Installed cost per kilowatt-hour
Inverters	US$100	150W
	US$215	300W
	US$360	500W
Batteries	US$35	Deep discharge, 40Ah
	US$60	Deep discharge, 70Ah
	US$100	Deep discharge, 115Ah
	US$140	Deep discharge, 150Ah
Generators	US$900	1000W
	US$1700	3000W
	US$2800	6000W
Diesel	US$1.65/L	Available in Kien Svay
Bricks	US$0.15 each	Clay bricks are fired in the village kiln
Wind speeds	3.1m/s-5.5m/s	
Wind turbine	$1500/$kW_e$	Installed cost per kilowatt
Mean wages	US$2-4/day	

Bermojur Kachhari Ghat, Sunderbans, West Bengal, India
Latitude: 22º 32'N Longitude: 90º 20'E
Time Zone: GMT +5:30

The Sunderbans is part of the world's largest delta and is interwoven by a network of small rivers, creeks and waterways. There are roughly 50 habitable mangrove-forested islands just above the sea level, which are protected from high tides by bamboo reinforced clay dikes. Bermojur Kachhari Ghat is a village of about 1000 people located on the island of Sandeshkhali. To reach Sandeshkhali from the main city of Kolkata, people travel by road for 3 hours until it ends in Najat, a small port town. From Najat, Sandeshkhali is a 1 hour boat ride away. Access is even more difficult between the months of April and September, when cyclones plague the area with destructive high-speed winds and monsoon rains flood the area.

While the town on mainland has an electrical grid, it is too difficult and costly to extend transmission lines across rivers and creeks to reach islands in the Sunderbans. None of the households in Bermojur Kachhari Ghat have electricity and most families use kerosene lanterns or candles brought by boat from Najat. Relatively cheap Chinese-made generators and diesel can also be purchased on mainland, but the Indian government recently raised the price of diesel by $0.04/L in response to an increase in the price of crude oil. While there are currently no diesel generators on Sandeshkhali island, a few wealthier households on neighboring islands have them. The main livelihoods in Bermojur Kachhari Ghat are rice farming, fishing, or catching tiger prawn spawn and selling them to commercial farms that produce giant tiger prawns for export. Many households also own a few sheep and some chickens, but goats and cows are rarer because of the difficulty of raising them in a wet island environment. Most available cow dung is dried and used for cooking. The region also has around 300 days of sun and average wind speeds of about 5 m/s. About 20% of the inhabited islands are currently using solar photovoltaic systems and the nearby Bengal tiger reserve uses small windmills to power water pumps. While there are some fast creeks and rivers in the Sunderbans, their paths and speeds can vary widely and unpredictably. Sandeshkhali island is situated between two of the larger and slower flowing rivers.

The island has a long and narrow shape that is approximately half a kilometer by 10 kilometers. Bermojur Kachhari Ghat is located on the southern half, and another village is located on the northern half. Generating the political will for infrastructure development projects on the island is often complicated, because the two villages may not agree on where to site the projects. On the far north end of the island, a local NGO called Friends of the Sunderbans has recently built a primary school and health clinic to serve both villages. Few of the adults are formally educated and while there is interest in an evening vocational training program, it has been difficult to implement without any lighting at the school. The new health clinic is also limited by a lack of equipment.

Supplies are brought in periodically from mainland and a small 50W refrigerator has been donated, but there is no electricity for it to be utilized. Friends of the Sunderbans is currently prioritizing the refrigerator for vaccines and medicine, because the only 3 water wells were broken and contaminated during a cyclone earlier this year and there is fear of a cholera or typhoid fever breakout on the island. A senior staff member at Friends of the Sunderbans has expressed interest in becoming a co-investor or providing a low-interest loan for a small photovoltaic system. The villagers do not have much cash on hand, especially after the financial strain from repairing damages caused by the recent cyclone. Most households have already used their savings by contributing to a village-wide fund for the reconstruction of wells and homes, food and other immediate needs.

Some of the major organizations that could be approached as potential resources of capital support include

- Friends of the Sunderbans, a local NGO run by Aunt Nilima, built and operates a primary school and health clinic on Sandeshkhali island
- West Bengal Renewable Energy Development Agency, a government program which has disseminated solar and wind energy to some villages in Sunderbans (http://www.wbreda.org)
- SELCO Solar Pvt. Ltd, a social enterprise that provides sustainable energy solutions and services to under-served households and businesses in India (http://www.selco-india.com)
- The Energy and Resources Institute (TERI) in India and the Market Facilitating and Enterprise Development Organization (MFEDO), entities that jointly set up a pilot project in the Sunderbans where women are trained to be solar power entrepreneurs (http://www.terina.org/docs/Sunderbans.pdf)

These are some of the *current* big players that may be relevant to energy access in this area. Rural electrification has been a high priority for the government of India, and energy access is one of the key factors in economic development.

Not all information needed to present a strong report is necessarily contained in this document. More outside research (include sources and verify their reliability!) and careful consideration of conditions will be needed to make a strong assessment and design an appropriate system.

Table 1 Selected Prices and Information

Photovoltaic panels	US$0.50/kWh	Installed cost per kilowatt-hour
Inverters	US$100	150W
	US$210	300W
	US$350	500W
Batteries	US$35	Deep discharge, 40Ah
	US$60	Deep discharge, 70Ah
	US$100	Deep discharge, 115Ah
	US$135	Deep discharge, 150Ah
Generators	US$800	1000W
	US$1600	3000W
	US$2700	6000W
Diesel	US$1.55/L	After the government price hike
Average wind speeds	4 m/s	November-February
	6 m/s	March-June, not including cyclones where winds can reach speeds of over 200km/h
	5 m/s	July-October
Wind turbines	$1500/$kW_e$	Installed cost per kilowatt
Mean wages	US$1.50-3/day	