Khost Province
Renewable Energy Resource Initial Assessment & Recommendations
USAID Afghanistan Clean Energy Project (ACEP)
January, 2010

EXECUTIVE SUMMARY

The Khost PRT proposed four wind and hydro electrification projects for the Nadir Sha Kot and Tani districts. ACEP conducted a preliminary assessment of the renewable energy resources in Khost and found that wind resource is poor. Likewise, hydro resources are relatively scarce. The solar resource is excellent. Khost security makes implementation of large civil works projects (e.g., hydro,) difficult. Likewise, centralized power projects are insurgent targets. The recommended approach for Khost is to implement decentralized solar home systems that local technicians can be taught to install; these will meet basic electricity needs, be a lesser target, and create local jobs.

KHOST PROVINCE

Khost province is 4,152 km^2 and located in south-eastern Afghanistan bordering Pakistan. The provincial boundary is ~120 km southeast of Kabul. The provincial primarily Pashtun population is about 640,000 persons. Khost City is the capital and lies at 1,146 meters with ~160,000 people. Khost (Shaik Zayed) University was re-opened in 2008 with UAE assistance and has ~3,000 students.

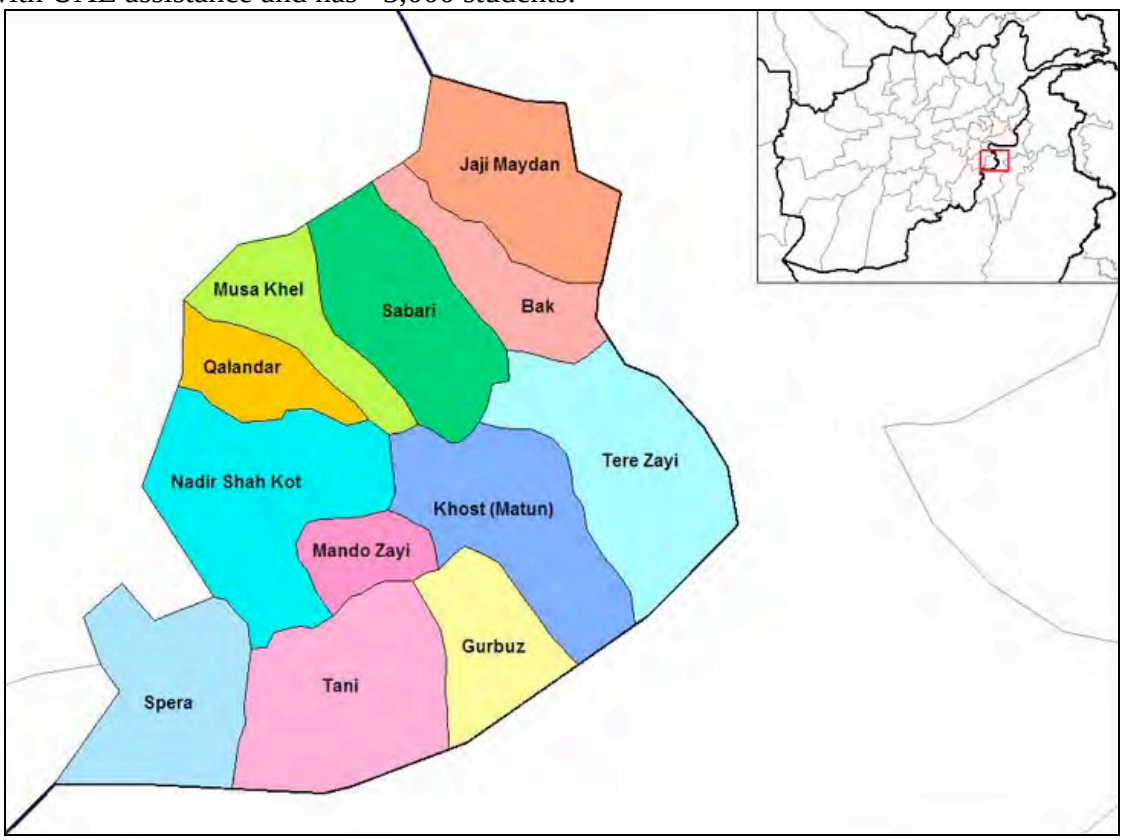

Fig. 1. Khost province and political districts in southeastern Afghanistan (Wikipedia).

Khost Province is essentially shaped like a bowl, with a semi-arid plain ringed by mountains. In Khost, climate varies with altitude, from colder alpine zones in the high mountains to hot semi-arid plains in the summer at lower eastern elevations. Western Khost province mountains range from 2,000-3,000 meters topping out with a 3,500 m peak on the border with Paktia. These higher elevations are the source of most of the water for Khost. Elevations drop rapidly to about 1,000 meters to the East. Most roads in Khost are unimproved and many areas are inaccessible by road.

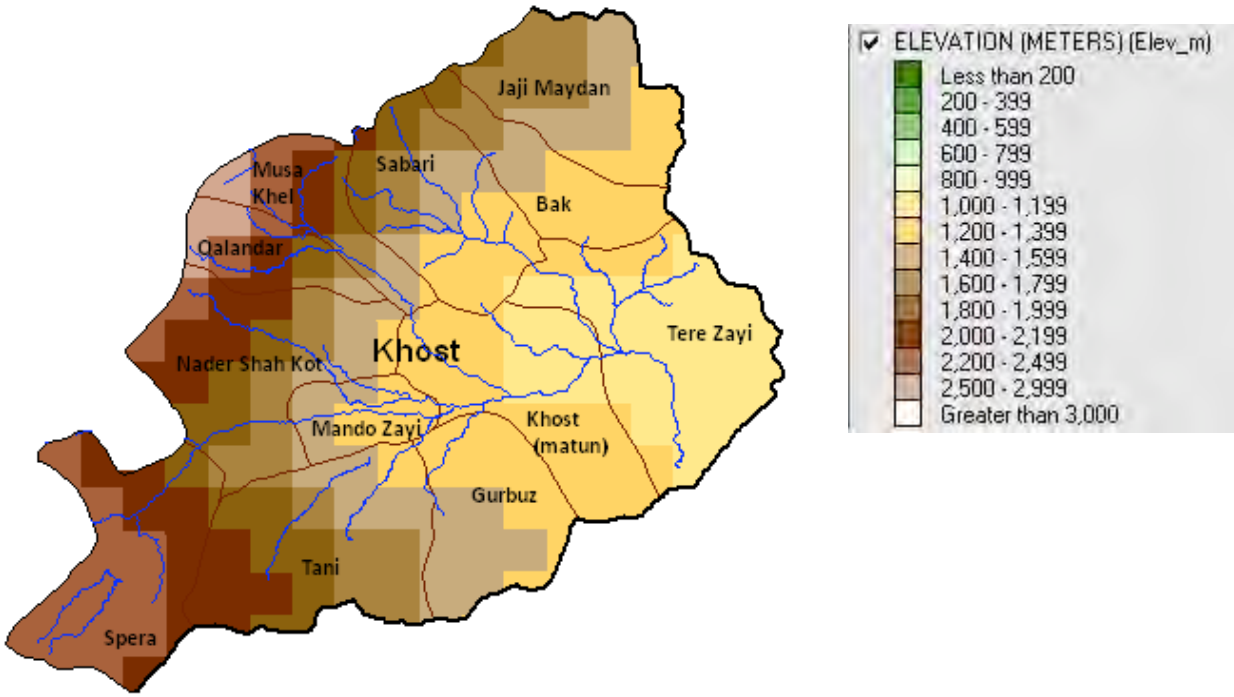

Fig. 2. Khost Province elevation map and drainages (NREL).

Khost City winters drop down to freezing at night, while it is hot in the summer approaching 35°C for highs. The upper elevations in western Khost are much colder.

Table 1. Khost Monthly Average Temperatures

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Max °C	13	14	19	25	30	35	34	32	31	26	20	15
Min °C	0	1	6	10	14	20	21	21	17	10	4	0
Mean °C	5	7	12	18	23	28	27	26	23	18	11	6

weather network

The Khost rural villagers are living in residences with typically six or seven people. The key economic activity is agriculture, although there are some local handicraft, carpentry, and metal workshops. Access to cash is difficult and monthly incomes are 5,000 AF per month. Many men form the rural communities have left to work in Dubai, Saudi Arabia, Iran, Qatar, etc. to provide cash to help maintain their families back in Khost.

WIND RESOURCE

The wind resource is the most fundamental consideration in finding suitable sites for wind energy development. A proposed site for power generation must be in a consistently windy location. The wind blows everywhere at times, but suitable sites for wind energy projects must have consistent wind available most of the time throughout the year to be viable for village power.

Wind power maps indicate the wind power potential over a geographical area. Map estimates made by Dennis Elliott of NREL for Afghanistan extrapolate data between sites where wind power values are known and comparing to upper atmospheric data and topography. In 2007, NREL published a detailed, high resolution wind map for Afghanistan. The map details Afghanistan wind data using 1 km square grids. The NREL Afghanistan general wind energy map for 50 m height is provided below (1 km^2 resolution). Initial estimates are that western and northern Afghanistan have excellent wind energy potential.

NREL wind maps indicate good wind resource in northern and western Afghanistan. However, wind resources in southeastern Afghanistan are notably lacking. Thus, wind projects proposed for Khost are unproven and any wind projects implemented would be failures. Wind assessment could be monitored in certain areas to verify findings, however this is only likely to verify NREL's assessment at great cost and risk, and simply is not worth the verification effort.

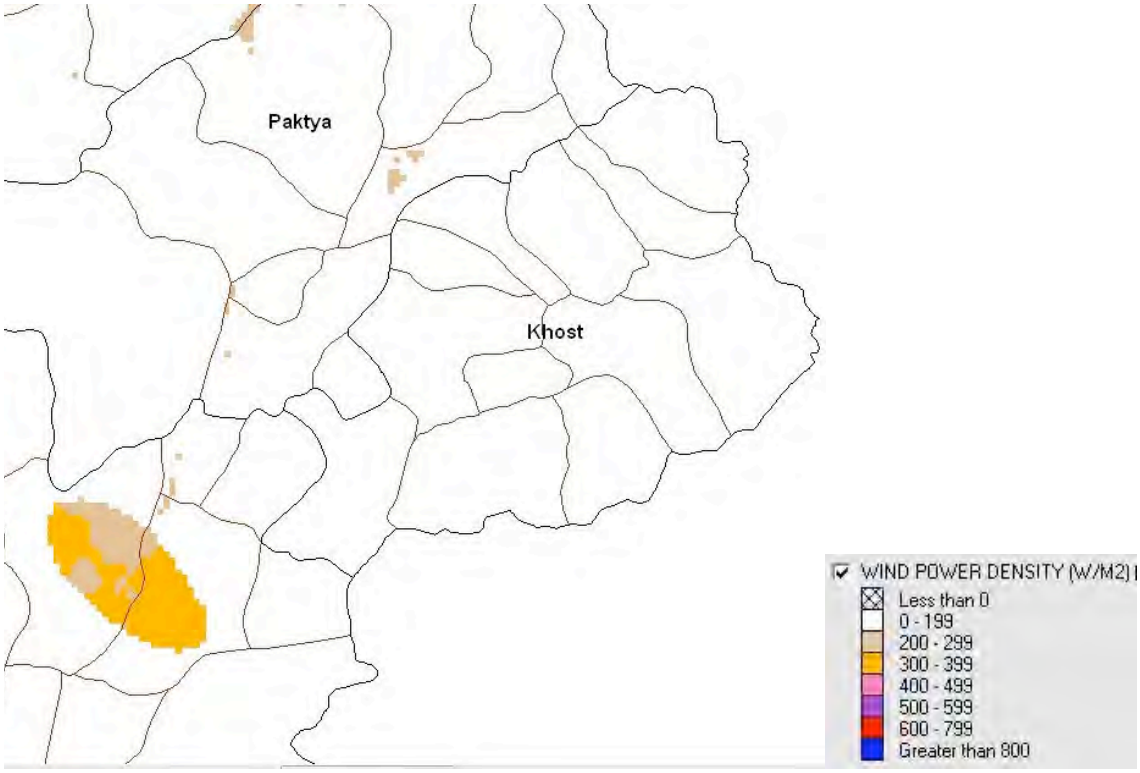

Fig. 3. Khost annual wind resources are poor across the entire province (NREL).

HYDROLOGICAL RESOURCE

The Khost province hydrological resource is centered on the Shamal (Matun) River, which runs diagonally across the province, carrying water from the mountains into the Khost basin. Unfortunately, Khost province receives relatively sparse seasonal rainfall and only averages less than 500 mm (<19 inches) in a year in Khost City, as shown in Table 2. What little water there is runs off quickly and carries lots of sediments with it due to lack of vegetation cover. There are no large water storage reservoirs in Khost. As a result, there is an almost perpetual water shortage. Erosion is problematic and erosion control is essential to slow the water down and improve availability and quality. Overall, the water resource in Khost is limited with lots of sediments when it does exists. Thus, good hydropower opportunities are rare.

Figure 4. Khost major rivers and drainage system.

Table 2. Khost Monthly Average Rainfall (mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Total (mm)	26	54	62	65	40	22	76	62	31	8	12	21

weather network

Table 3. Shamal (Matun) River Monthly Flow in Khost City (m3/sec)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1962	0.16-0.2	0.18-.033	0.2-1.06	0.67-4.2	1.57-7.6	1.2-1.86	0.93-1.27	0.44-1.96	0.24-0.93	N/A	N/A	N/A
1963	0.36	0.34	0.27	0.28	0.30	0.35	0.46	0.24	0.25	0.56	0.32	0.43
1964	N/A	N/A	N/A	1.86-7.35	7.35-3.02	N/A	N/A	N/A	N/A	0.18-0.1	N/A	N/A
1965	average 0.24 - 3.7 m3/sec											
1966	average 0.16- 2.33 m3/sec											
1967	average 0.11- 2.43 m3/sec											
1968	average 0.04 - 0.53 m3/s											
1969	average 0.06 - 0.76 m3/s											
1970	average 0.1 - 0.72 m3/s											

Water Regulation Dept., MEW

The ACEP team visited potential Khost hydro project sites like the Shamal (Matun) and Mazhgor rivers to determine flow rates. Flow data is also available from the 1960's from MEW as shown in Table 3. These 40+ year old flows are actually better than expected flows today given increased deforestation in Khost since that time. Water flows are frequently low and sometimes the rivers can run dry. The structure of the valleys is composed of rocks, sand, and very small amount of soil. The watershed suffers from significant erosion problems. Because of the high erosion in the area, significant sands and other sediments are carried in the water stream, which are harmful to hydro turbine runners and other parts which are in direct contact with the water flow.

There are possibilities to construct settling dams. This can help drop out the suspended solids, but will not increase the long term flowrates. Water flow ranges from beginning of valley up to the Matun area from 20 to a about 400lps. If a good quality turbine was installed, these rivers may be able to produce about 10-20 kW of power, if commonly found more inefficient local crossflow turbines are used, maybe only about 5 kW can be produced. In both rivers year round hydro power generation is not possible in the dry season (e.g., in 1968-69). According to Afghan water management laws, water should be used first for drinking, than for irrigation, and lastly for industries (including power generation). Overall, Khost Province has limited hydro potential. MEW should set up a more thorough hydraulic monitoring system for Khost to better assist with provincial water management and determine future hydro potential.

SOLAR RESOURCE

The solar energy resource in Khost, as in most of Afghanistan, is quite good and widespread. The solar radiation received in any instant is known as irradiance, measured in Watts per square meter. The maximum irradiance that a surface receives is about 1,000 W/m^2, which is considered the standard used for rating solar collectors. Solar maps are given in terms of insolation, which is energy and corresponds to the accumulated irradiance over time. Insolation is typically measured in units of kilowatt-hours per square meter (kWh/m^2). Normally, this value is reported as an accumulation of energy over a day. Insolation is also expressed in terms of peak sun hours. A peak sun hour is 1,000 kW/m^2. The energy produced by a solar electric (photovoltaic-PV) array is directly proportional to the amount of insolation received. Insolation is a key parameter in the design of solar systems. The map below shows the average annual solar insolation for a horizontal surface available across Khost (NREL).

Note that the maximum solar energy available for any fixed array at a location is for latitude tilt. However, the tilt of the array may want to be maximized for wintertime if needs warrant (i.e., more vertical tilt).

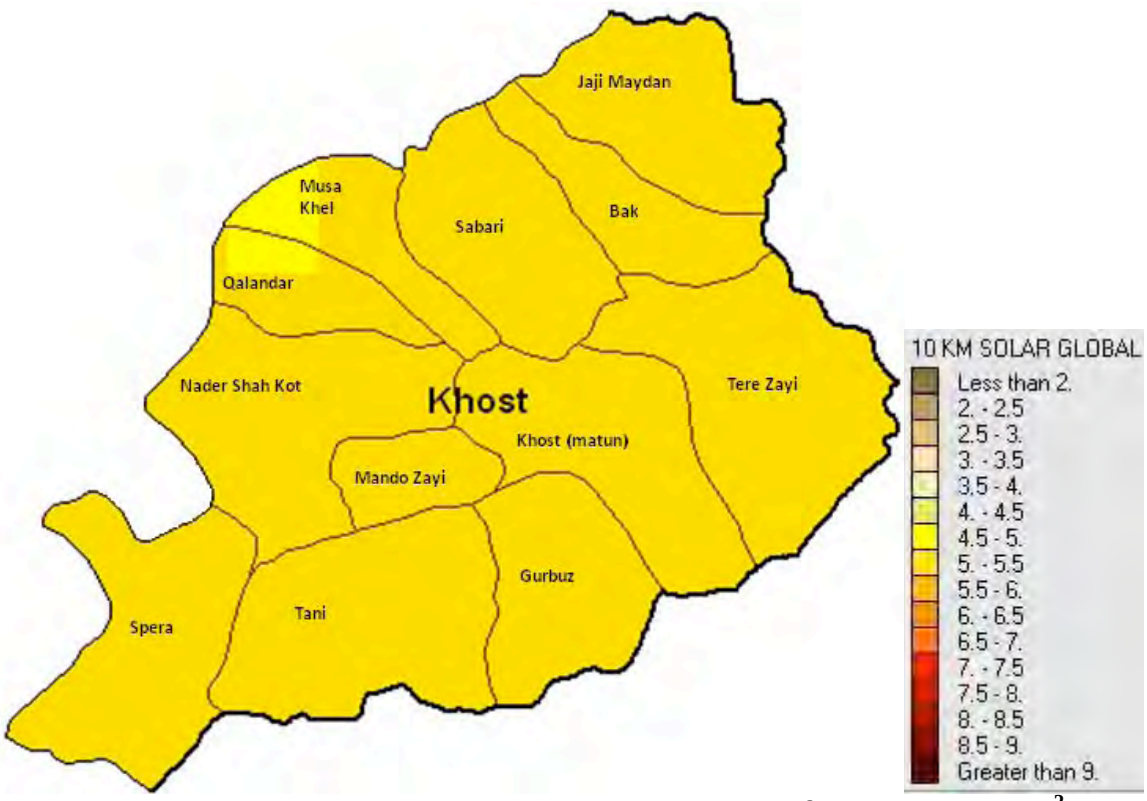

Fig. 5. Annual Average Global Solar Horizontal Insolation for Khost (kWh/m^2/day)
(NREL)

Table 4. Khost Monthly Average Global Horizontal Solar Insolation (kWh/m2/day)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
Sun-hours	2.9	3.6	4.8	5.9	6.8	7.1	6.8	6.2	5.8	4.9	3.5	2.9	5.1

NREL

Capturing solar energy typically requires equipment with a relatively high initial capital cost. However, over the lifetime of the solar equipment, these systems can prove to be cost-competitive especially since there are no recurring fuel costs, as compared to conventional energy technologies (e.g., about ½ of diesel generator costs over 20 years) or grid extension. In the case of Khost, the least cost option for providing basic electricity services to many rural homes is going to be stand-alone photovoltaic systems. Khost has excellent solar resources that can be applied widely across the entire province.

Khost PRT Original Project Nominations

The Khost PRT worked with the RRD Director to consider and review project nominations. The RRD Director selected and the PRT nominated four sites (two of which were visited by the PRT at time of nomination). These were in the districts of Nadir Shah Kot, which has a total population of about 37,000; and Tani which has a population of about 67,000. Sites ranked in order by the PRT are as follows:

1. Nariza, Tani, 120 kW proposed micro-hydro project

This village of approximately 7,000 people living in about 1,000 residences is located about 35 kilometers from the electric grid in Khost City. There is an estimated 120 meter water head at this site. The community is characterized as one where significant community participation can be expected. MRRD expects this project to supply electricity and also support crop irrigation needs. The original PRT proposal was to electrify about 250 homes with the hydro resource.

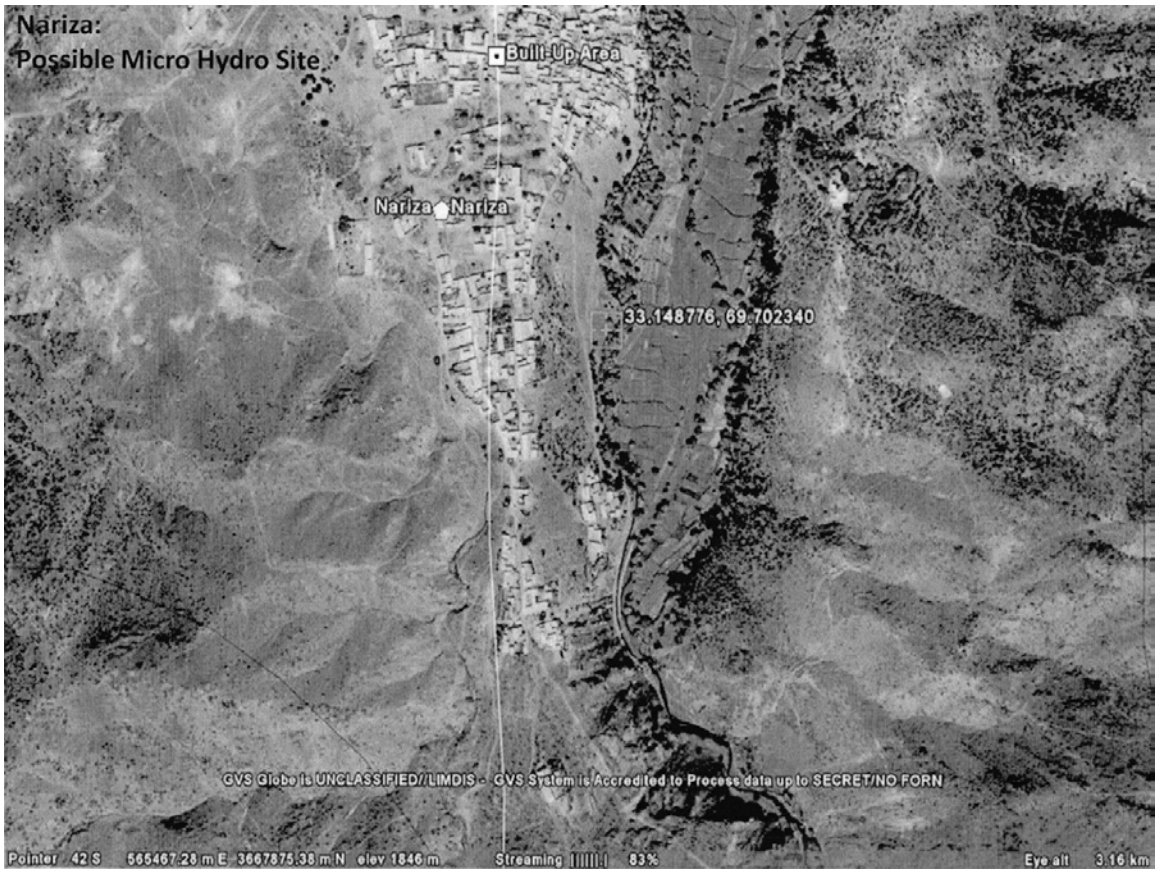

Fig. 6. Nariza village aerial view and topography.

2. Almara, Nadir Sha Kot, 100 kW proposed wind project

Almara has about 5,000 people living in about 1,000 homes in this village, which is at ~1,705 meters elevation and lies about 30 km from the existing electric grid. The PRT requested approximately 30 kW electric power supply for 500 homes from wind energy. MRRD selected this village for wind electrification because it felt that there were consistently high winds (the PRT also observed a windy day during a site visit). However, consistent long term winds are needed and the NREL wind map shows a generally poor resource. On-site wind monitoring is needed to justify the investment of a wind power system.

The site is very near the Khost-Gardez road and is a high-priority for the PRT. The village is cooperative and an elder has been cooperating with construction efforts with the Kabul-Gardez road. MRRD confirms strong local support for bringing electricity to the village, and a willingness by villagers to participate in the security and management of a project, as well as provide labor resources during the construction phase. The PRT does have concerns that the project will be noticed by passing motorists and may increase the village security profile.

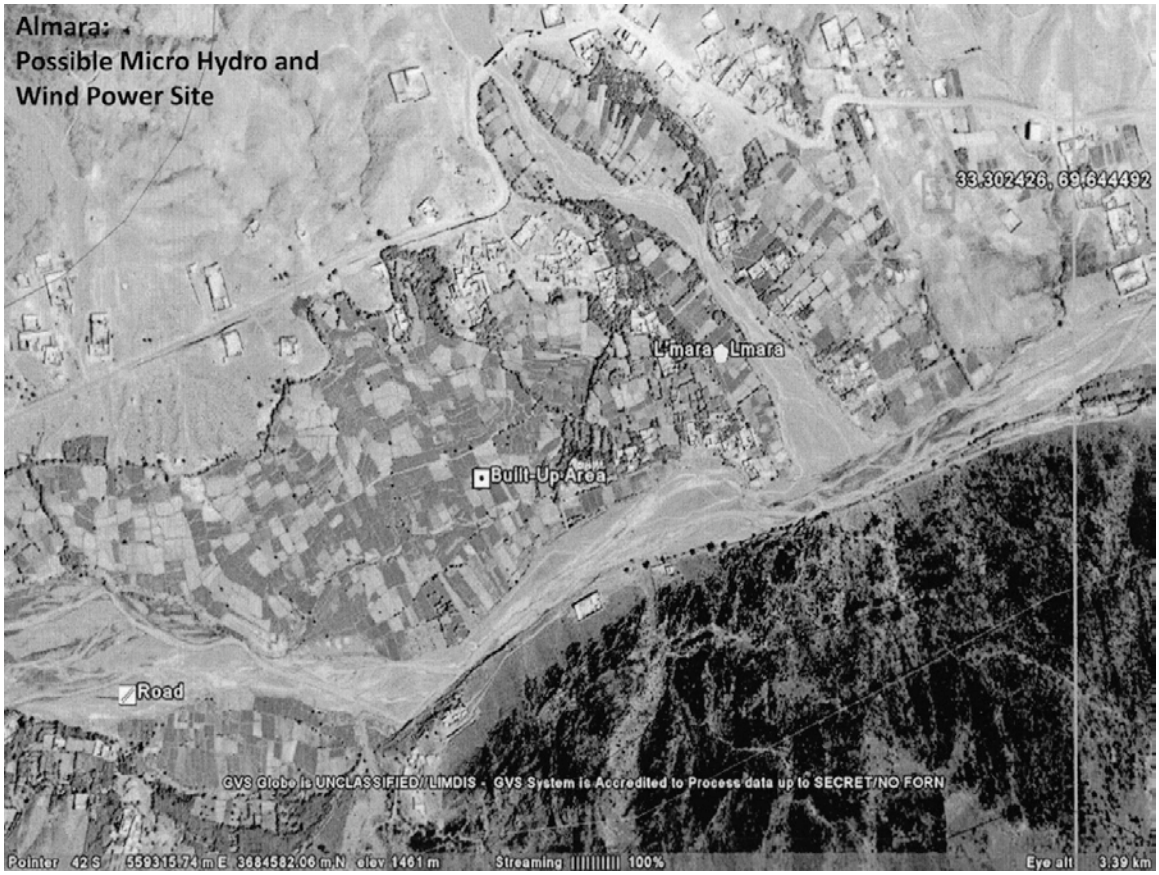

Fig. 7. Almara village aerial view and topography.

3. Gedawara, Nadir Sha Kot, 100 kW proposed wind project

Gedawara is estimated to have a village population of 5,000 living in about 1,000 residences. The village lies about 27 km from the electric grid and is at an elevation of about 1,700 meters. The site is near the Khost-Gardez road and is a high-priority for the PRT. MRRD selected this village for wind electrification because it seemed to them that there were consistently high winds. MRRD indicates the village is interested in the project and understands the benefits.

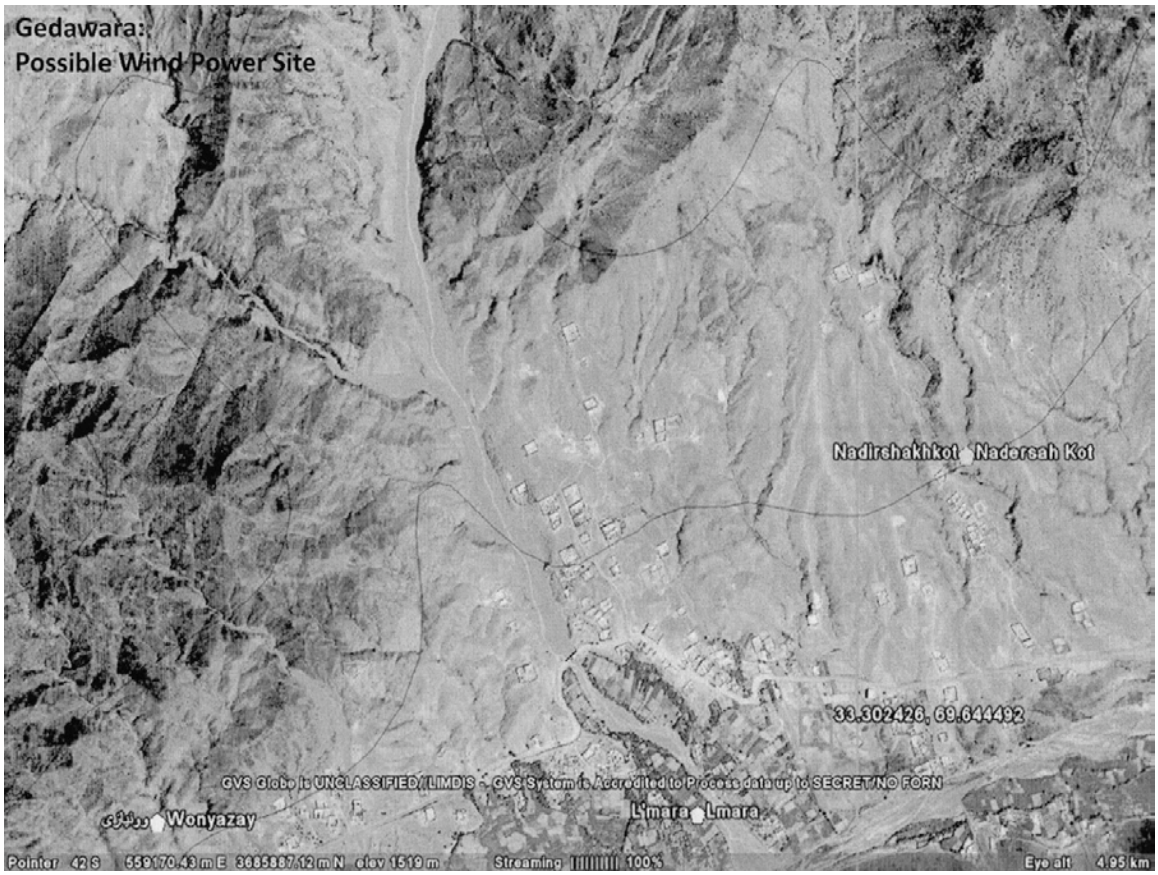

Fig. 8. Gedawara village aerial view and topography.

4. Almara, Nadir Sha Kot, 30 kW proposed micro-hydro project

The current micro-hydro unit does not function and requires rehabilitation; it is not clear if it was a failure to maintain the unit due to lack of training and/or because of the impact of heavy rains. The PRT conducted an initial site visit and assumes the village leadership will sustain a rehabilitated micro-hydro project if adequate training is provided.

The PRT and RRD Director have evidently made many efforts to review these sites, but have not been able to visit all due to security concerns. These nominated projects have not completed Khost's Provisional Development Council (PDC) approval process and is required before any final provincial consideration is possible. The MRRD Director is prepared to submit these projects for the PDC's consideration upon feedback from ACEP.

Khost Field Assessment
January 13-17, 2010

ACEP Field Survey Team:
Eng.Mirza Mohammad Rahmani (ACEP, Hydropower Engineer)
Eng.Gul Rasool Hamdard (REDO, Director)
Eng.Ghulam Naqib (REDO, Surveyor)

Assisted locally by:
Eng. Omar (MRRD, Director)
Eng. Mahomad Jan (MEW, Engineer)
Eng. Maeel (DABM, Director)
Eng. Qarimee (DABM, Technical Manager)

The ACEP field team traveled from Kabul to Khost early on January 13, but was delayed and did not arrive until 4:00 p.m. due to an IED detonation that had closed the Gardez-Khost road for several hours. The team also had the opportunity to travel through Nadir Sha Kot on the way to Khost City and observe the hydro resources of that river system as well., which had flow rates of less than 250 lpm and was not sufficient to generate more than 10 kW of power.

Immediately after arriving in Khost, the ACEP team was able to first meet with the Khost Power Company (DABM) Director to ascertain the province's energy needs and current power situation. The Director was also kind enough to allow ACEP team members to stay at the power station facilities while in Khost for four nights. The Town of Khost is powered by 3 diesel generators with the total capacity about 1900 kW. The total city load during the evening is about 600 kW. For grid extension DABM needs a smaller capacity transformers from 10 – 50 kwa (20 kv/0.400). Than the whole city can be electrified via the existing diesel plant.

The following day (Thursday), the field team held their first meeting with Eng. Omar, the Khost MRRD Director. The team discussed the original PRT proposal to electrify the rural communities in Nadir Sha Kot and Tami. The Director was interested in providing sustainable, renewable energy options to the remote villages. The Director appeared interested in supporting ACEP's efforts to provide training to community members on construction, maintenance, and operation skills. He also though community contributions would be made, mostly in the form of labor. He anticipates that the villages selected would see the projects as valuable assets and be willing to offer security protection.

On Friday, the ACEP team observed the water resource of the Shamal river in Khost City part of which comes from Tani. The Shamal river had flow rates of less than 250 lps and was not sufficient to generate more than 10 kW of power. The team extrapolated that the Tani village site (Narizee) would have similarly low flows.

The team also met with MEW in Khost .The result of these discussions concluded that for the most part, the lower bowl portion of Khost where most people live have generally low

heads and water flows and do not have micro-hydro potential. MRRD suggested evaluating the location of Mazghor. This site was felt by MRRD and MEW to have best hydro resource in lower Khost was located in Mazghor and that the team should visit that area to assess viability.

Fig. 9. Available water supply for possible Mazghor River Dam for Khost.

The field team visited the Mazghor river on Saturday, since Mazghor was indicated by MRRD and DABM to be one of the best potential sites for hydropower in Khost. The Mazghor location lies about 7 km away from Khost city. Water from this location comes from springs fed from Sotiy Kandow Pass watershed which starts14 km. away from Khost City. The ACEP field team took the necessary flow measurements and surveyed the potential for a hydropower dam.

Fig. 10. Potential site for a hydroelectric dam at Mazghor (10m max height).

Masghor River Potential Damsite:

Q = 0.300 to 0.220 m^3/ sec (Flow)

Mil = 2 % (Slope)

L = 1.5 Km (Water Dam Area)

D = 78 m (Dam Width)

Flow rate from at the headwaters start out at about 20 lps and by Khost the flow rate increases to about 250 lps. However, the quality of the water is very poor. Sand and gravel flow in with the water, therefore requiring a settling reservoir. Otherwise the micro-hydro turbine would be destroyed in short order from the grit. Given the site limitations and that the main Khost road parallels the river, the height of the reservoir cannot be more than 10 meters. Thus, the site does not permit the practical construction of a needed reservoir.

Fig. 11. Water supply at Mazghor potential damsite with Khost MRRD Director Eng. Omar.

The field team had also planned to go to the Nariza village site on Saturday as well. However, Eng. Omar, MRRD director informed the ACEP team that the Nariza visit was cancelled and that he would be unable to go. MEW also informed ACEP that security to visit the site was difficult and that the team should not go unaccompanied. Thus, ACEP was unable to evaluate the village hydro resource directly, but did observe the water resources further down the watershed on Friday and concluded that hydro potential was again most likely limited and of poor quality as was found in most of Khost.

It should be noted that logistics and planning were difficult for the field team with the local partners frequently cancelling or moving site assessments around despite the fact the team was on a limited schedule. Over the fout days, the field team was scheduled to meet three times with Mr. Kawsar, the Khost PRT Afghan liaison. However every attempt to meet with him was cancelled by him due to security concerns. Initially Mr. Kawsar promised to meet with the ACEP team on Thursday, but was then unable. Then he proposed to go with ACEP to conduct field visits at 14:00 on Friday; but called at 20:00 later that same evening to apologize and rescheduled again for Sunday. ACEP requested that he arrive Sunday morning at 0800 at the DABM office, but again he was a no show. By this time, ACEP had already conducted sufficient assessments to verify that Khost had limited hydro resources. The field team returned afterwards Sunday morning to Kabul.

The general conclusion of the field team after observing the major Khost river systems of Nadir Sha Kot, Shamal, and Mazghor is that there is limited hydro resource and thus low potential for hydro power generation in most of Khost. There are a few specific locations where it is possible to generate from 5-10 kW during peak flow season, but probably not the 30-120 kW that the PRT was seeking for Nadir Sha Kot and Tani. The limited hydro potential can be useful in some cases good for running small flour mills, private nano-hydro, etc. There is one town Domanda where there may be possibility for a 50 kW micro-hyrdo project. The town network currently uses 1.5 MW of diesel generators, providing electricity to 1,865 consumers able to use their appliances for a limited six hours in the morning and six hours in the evening. Additional survey of this site is needed.

In summary, the field assessment found relatively little hydro potential in Khost. The ACEP team did find that many villagers understand the benefits of stand alone solar energy systems and that such systems would be well received. Overall conclusion from the field visit was that the best approach for most of Khost given the limited solar and wind resources is to deploy stand alone solar energy systems to meet village power needs.

SECURITY ISSUES

Security threats underpin all development efforts in Khost. The province is a stronghold of the Taliban movement, and security is compounded by its proximity to North Waziristan in Pakistan where the Haqqani network is based. The city of Khost has endured many significant Taliban attacks from this network. Likewise, Camp Chapman Base where the PRT has been regularly attacked and was the site of the recent deadly suicide bombing of CIA operations on December 30.

Already 2010 is off to a violent start in Khost. On January 4 a dozen gunmen attacked vehicles of the Mine Clearing Planning Agency (MCPA), whose staff members were beaten and robbed. IEDs remain the weapon of choice of AOG. Khost has seen an increasing number of IED-related strikes against high profile targets. There was an attack on January 7 inside the Governor's office, which injured 8 people including the Acting Governor. Government employees including troops and police are frequent targets.

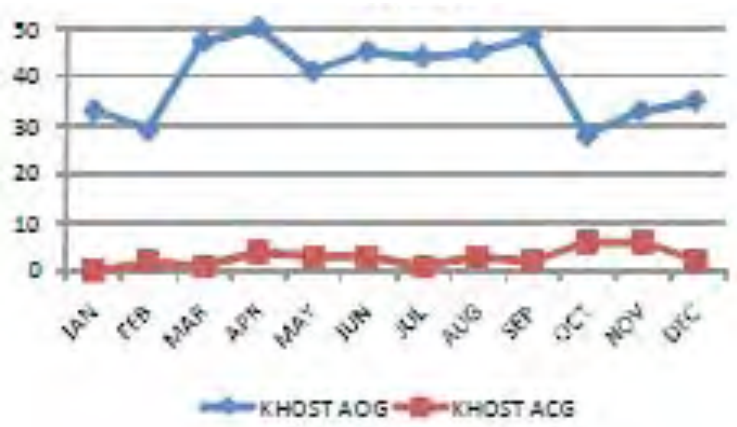

Fig. 12 Khost AOG and ACG monthly incidents in 2009 (ANSO).

While ACEP personnel were in Khost, apparently AOG elements were informed of the that outside power engineering experts were in the city. As a result, a power distribution panel was exploded in defiance. One week earlier, the power station itself was attacked by Taliban insurgents and two DABM employees were killed and the son of the plant director was injured. Thus, centralized power production facilities, as well as power technicians working in Khost are viewed as a legitimate target by the Taliban insurgents.

Fig. 13. Insurgents blew up a Khost City power distribution panel during the ACEP field team visit.

Khost Province as a whole remains a dangerous environment for operations and travel. The Khost-Gradez road is perhaps the most dangerous in the country due to the Taliban activities and numerous IEDs. Centralized power systems are also a target as was demonstrated during the ACEP visit to Khost City when a power distribution panel was bombed. Thus, working in Khost on renewable energy development projects presents significant challenges and risks.

RECOMMENDATIONS

Given the lack of wind resource, and likewise relatively limited and poor quality hydrological resource in Khost, ACEP recommends taking advantage of the province's abundant solar resource to develop a viable rural electrification approach that can be widely applied across the entire province.

Likewise, given the difficult security situation and insurgent readiness to target centralized power facilities, it is recommended to take a decentralized approach with solar electrification of individual households. This disperses the power generation across a wide area, so that even if a few systems were targeted, the majority would still be unaffected. It is also unlikely that the insurgents would target individual Pashtun privately owned home solar power systems.

These smaller photovoltaic solar home systems (PVSHS) are relatively simple to install and with some basic training, can be installed directly by local technicians directly from the communities. These technicians can be trained through ACEP. This helps created greater sustainability and creates long term O&M jobs in the local economy.

The PVSHS can be provided as prepackaged systems engineered for small scale rural electrification and long life. While NSP has been installing low quality 20 Wp PVSHS, ACEP will upgrade the quality and size of the installations to at least 50 Wp. Typical PVSHS consist of one PV module (e.g., 50 Wp) either mounted on a pole or rooftop. The PV module charges a nominal 12V deep cycle lead acid battery. Sealed batteries can be chosen that never require watering and are maintenance free. All batteries should be installed inside a spill proof case strapped shut to prevent children from tampering with. Charge regulation can be maintained through a fused solid state charge controller. Likewise, the system will use a appropriate dc overcurrent protection.

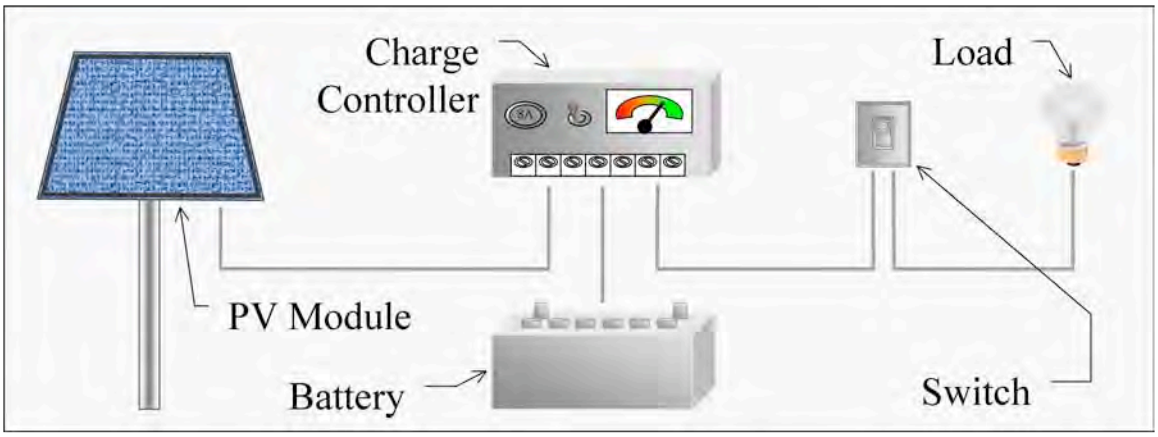

Fig. 14. Example PV solar home system (PVSHS) setup recommended for Khost.

The PVSHS system can be used to power either LED or fluorescent lamps with electronic ballasts. ACEP recommends using a combination of both types of lights. A dc-dc voltage converter and plug can be included to allow for use of different types of appliances, such

as dc radio and/or TV. Given that Khost insolation average of about 6 sun-hours/day at latitude tilt, and assuming an overall PV system efficiency of 60 percent for a fairly well designed system (i.e., including battery efficiency losses, module temperature derate, line losses, etc.), the user could expect on average to have about 180 Wh/day of available power. Of course, there are seasonal variations and double or more power could be extracted from the battery on any single day, but could not be sustained long-term. As is typical for solar energy users, they quickly learned to live within finite energy system bounds and learned to ration energy use during extended cloudy periods, which are fortunately are relatively rare in sunny Khost.

It should be noted that the NSP has implemented a number of small PVSHS throughout the country, but that these systems have been problematic. The problem has mostly been with undersized systems, bad design, and poor quality installation of the systems. Typically these systems have only provided 20 Wp and have used shallow cycle automotive batteries which are entirely inappropriate for this kind of deep cycle application and typically only last from 9-18 months. ACEP will implement much higher quality and larger systems that will last many years with little maintenance required.

With PVSHS approach, it is possible to meet all of the PRT community electrification goals. Based on MRRD/PRT goals, this includes about 500 homes for Almara, 500 for Narizee, and 150 for Gedawara. Thus a total of 1,150 systems are proposed to be installed.

An experienced crew of two technicians can install about three 50 Wp PV systems per day on average. Thus, for 1,150 systems anticipated in Khost, it will take approximately 750 man days to install. At a minimum, two crews are recommended per village, which means about 3 months would be required to install all systems in the larger villages.

PROPOSED WORKPLAN

ACEP will work closely with MMRD and its community liaisons to implement village wide solar electrification efforts with individual photovoltaic solar home systems (PVSHS). MRRD will be responsible for identifying and selecting potential technicians that can be trained to install PVSHS in their communities. ACEP will be responsible for procuring hardware and providing training. The proposed required steps are as follows:

Task 1: System Procurement

- Design basic PVSHS to international standards for quality and safety.
- Develop and issue appropriate bid package to Afghan companies, including a local training component to train local technicians.
- Select best bid based on price, quality, and experience.
- Procure solar home systems for Khost.

Task 2: Community Mobilization and Training

- Identify and train local technicians from the communties to assist installations.
- MRRD to select final home sites for installation with community participation expected.

Task 3: System Installation

- ` Install PVSHS with local technician support in the villages.

Task 4: Monitoring & Evaluation

- ` Conduct periodic assessments of system performance and satisfaction and make adjustments to future PVSHS electrification programs based on lessons learned.
- Support local Khost technicians to expand the solar systems market and create additional jobs.

EXPECTED RESULTS

- Installation of ~1,150 PV solar home systems.
- Creation of at least 12 local technicians capable of installing and maintaining PV systems.
- Basic electricity provided for use of lights, radios, and televisions for 1,150 homes.

EQUIPMENT BUDGET

The initial equipment budget (US$) for planning purposes only, including installation labor, is estimated as follows:

1,150 PV systems x 50 Wp x $15/Wp installed = $862,500

The equipment budget does not include any applicable Afghan taxes or freight charges, or extra security that may be required. Nor does it reflect ACEP staff time, communications, shipping, and travel. Final quotes will be provided by industry.