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AN ASSESSMENT OF RENEWABLE ENERGY OPTIONS AT BROOKS CAMP, KATMAI NATIONAL PARK AND PRESERVE

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INTRODUCTION

At the request of Brad Richie, NPS Alaska Support Office and manager of the Brooks Camp relocation project, a renewable energy team (RET) from the Department of Energy/Federal Energy Management Program (DOE/FEMP) conducted an on-site power system assessment at Brooks Camp. The assessment included:

- An evaluation of the current electrical loads at the site,
- An evaluation of the current facility power system,
- A review of the plans for the relocated facility and planned power needs,
- An assessment of the renewable resources and possible siting options, and
- The identification of potential opportunities for renewable power systems.

The RET activities were coordinated through Arun Jhaveri at the DOE Seattle Regional Office. The RET consisted of three members with extensive experience in renewable power systems and included Hal Post (team leader) and Mike Thomas of the Photovoltaic Systems Assistance Center at Sandia National Laboratories, and Jerry Ventre of the Florida Solar Energy Center.

This report, which is organized to address each of the bullets above, presents our findings and analyses of the information collected from the site assessment. The report also presents our recommendations on renewable energy options and electrical generation that could be incorporated in the relocated Brooks Camp facility.

Site Assessment

Brad Richie coordinated a site visit to Brooks Camp for the RET on August 10-11. Others who participated in the visit and provided information included Paul Button, Facility Manager for Katmai National Park and Preserve (Park); Ken Pendleton of the Alaska Support Office; John Bundy, Park Chief of Operations; Rick Clark, Park Chief of Resources; and park employees Al Gansch and Richard Sherman. A preliminary briefing of the team's findings and recommendations was provided to the Brooks Camp relocation design team on August 12 at the offices of Cash Barner Architects in Anchorage.

Facility Description

Brooks Camp is located on the shores of Naknek Lake, at the mouth of the Brooks River, in Katmai National Park and Preserve, approximately 30 miles southeast of King Salmon. Park Headquarters are located in King Salmon, a one-hour jet flight southwest of Anchorage. Access to Brooks Camp is by boat or float plane.

To mitigate the intrusion of human presence on bear habitat, Park plans call for the complete removal of facilities at the current Brooks Camp site and the development of a new Brooks Camp facility approximately one mile south of the existing site. The new 40-acre site is to be located on the Beaver Pond terrace, south of the Brooks River, and approximately one mile from the proposed float plane and boat landing area on Naknek Lake. A dense pine forest with a 40-50 foot high tree canopy covers the new site. The RET toured both the current Brooks Camp facilities as well as the proposed new site. We also visited nearby facilities at Brooks Lake that will be incorporated into the new Brooks Camp location and three diesel spill remediation sites (two in the current Brooks Camp and one halfway to the new site) that require electrical power for ongoing cleanup efforts.

We will not discuss details of the existing or new Brooks Camp facility in this report as these are discussed in detail by two Cash Barner Architects reports and various NPS documents provided to the team. These referenced reports and other exhibits are listed below.

1. Summary of Brooks Camp Electrical Usage for 1998 and 1999, prepared by Paul Button
2. Katmai National Park and Preserve Concessioner Utility Rate Calculations – Fuel Rates FY99, April 19, 1999, prepared by Richard Sherman
3. Katmai National Park and Preserve Concessioner Utility Rate Calculations – Electricity Rates FY99, April 20, 1999, prepared by Richard Sherman
4. Pre-Design Background Information – Brooks River Area Visitor Facilities Development – Katmai National Park and Preserve – June 24, 1999, prepared by NPS
5. Brooks River Area Visitor Facilities Development - Relocate Brooks Camp, Katmai National Park and Preserve - Schematic Design Program - June 16, 1999, prepared by Cash Barner Architects
6. Brooks Camp – Orientation Site Visit – June 28, 1999–July 1, 1999, prepared by Cash Barner Architects

ENERGY USAGE AT BROOKS CAMP

Brooks Camp is operated seasonally, typically from mid-May through September. From our experience, the mix of electrical loads is typical of remote sites. With the exception of some propane use (via 100 lb. bottles) for cooking, the existing Brooks Camp facility is nearly all electric.

Meter records provided by Paul Button (Ref. 1) for the most recent continuous 12-month period can be described as follows:

Month	Electrical Usage
May	12,000 kWh
June	25,000 kWh
July	25,000 kWh
August	25,000 kWh
September	21,000 kWh

The seasonal (yearly) total is 108,000 kWh, or about 800 kWh/day for the 135-day operating season. The NPS is responsible for about 60% of the total and the concessionaire (Katmailand) accounts for the remaining 40%. We estimate that at least half of this total load is lighting. The park power system operators estimate that the peak demand is 60 to 70 kW, although we expect the typical demand to be substantially less, perhaps 30 to 40 kW with nightly demand in the 10 to 20 kW range.

BROOKS CAMP POWER SYSTEM

Electrical generation at the existing site is provided by two side-by-side 100 kW Cummins diesel generators that are operated alternately on two-week maintenance intervals. Two large above-ground fuel storage tanks are located at the north end of the generator building and an above-ground fuel piping system extends to the shore of Naknek Lake to offload 3500 gallon fuel shipments barged to the site.

Park records (Ref. 2) show that Brooks Camp typically uses 20,000 gallons of diesel fuel per year, nearly all for electrical generation. The cost for diesel fuel at Brooks Camp is calculated by the Park to be $2.43/gallon, of which $1.67/gallon is delivery cost from King Salmon. The Park (Ref. 3) computed an electricity charge of $0.469/kWh effective for 1999 that includes all maintenance and operating costs for the existing power generation, but does not amortize the capital expenditure at the plant facility necessary to generate electricity. For the most recent 12-month period, we believe the actual cost for electrical generation at Brooks Camp is nearly $68,000 or $0.62/kWh, not including facility amortization. The emission cost of the existing diesel generators is also substantial. We estimate that the generators create 11,500 lbs. of NO_x,
240 tons of CO_2, 570 lbs. of SO_2, and 430 lbs. of total suspended particulates. Following National Park Service directives for emission cost, an additional $43,000 of emissions are produced seasonally.

Electricity is distributed throughout the Camp via 120/208-volt three-phase service, although the water pump appears to be the only three-phase load.

<u>Fuel Delivery</u>

To assess electrical generation at Brooks Camp, especially as it impacts the infrastructure requirements at the relocation site, it's important to examine the current fuel delivery process. A commercial fuel hauling service transports diesel from the supplier in the King Salmon area via road to the NPS Lake Camp on the Naknek River, approximately 10 miles from King Salmon. Here the fuel is loaded onto the NPS barge M/T Ketivik for the 28-mile transport to Brooks Camp via Naknek River and Naknek Lake. A typical fuel load is about 3500 gallons. Upon arrival at Brooks Camp, the barge docks on the lake shoreline and the fuel is pumped from the barge via the piping system to the storage tanks. Fuel delivery to the Camp occurs primarily during July, August, and September when the water level in the upper portion of the Naknek River is deep enough for the barge to operate. The last fuel delivery of the season must top off the storage tanks so that sufficient fuel is available at the site to operate the Camp during May, June and perhaps part of July of the following year while the barge waits for operational water levels out of Lake Camp.

POWER NEEDS FOR THE NEW BROOKS CAMP FACILITY

Our Approach

Our approach to helping the Park identify opportunities for renewable energy generation at the new facility follows a path that is absolutely necessary for any renewables project. First, determine how electrical energy is being used and generated, in this case, at the existing Brooks Camp. Next, identify opportunities to reduce this usage through conservation, load management, increased load efficiency, and fuel shifting to increase power system efficiency. Next, establish power system requirements for the new facility that are consistent with these opportunities, and finally, examine how renewables can contribute to these power system needs.

Energy Use Reduction

Current energy usage at Brooks Camp is very typical of many remote park facilities with which we're familiar. The diesel generators are oversized for the electrical needs, so very little concern exists for reducing energy use. During our visit, we found any number of energy use practices that contribute to significant energy waste. Several buildings had outside lights as well as inside lights that remain continuously on during the day, even though the buildings weren't occupied. In at least one case, the building lights represented a continuous 3 kW load. We also noticed that at least four electric dryers in one building, representing a 20 kW load, were operating at the same time that the dinner meal preparation was underway at the lodge. By delaying dryer operation away from meal times, the peak demand and the size of the power system generator would be substantially reduced. So how would this save energy? The current 100-kW diesel generator is using 20,000 gallons of diesel fuel to generate 108,000 kWh/year, or 5.4 kWh/gallon of diesel fuel burned. At maximum efficiency (fully loaded to rated capacity), a diesel generator could generate 11 kWh/gallon of diesel burned. What this means for the existing Camp is that a more appropriate-sized diesel generator, meeting nearly a continuous load equal to generator capacity, could generate the same 108,000 kWh of energy but use only half of the fuel currently burned. That's the role of load management. Improvement in load efficiency is a major opportunity for the new Brooks Camp. The replacement of incandescent light bulbs with high-efficiency fluorescent lights would reduce energy use by a factor of 4 while providing the same illumination. Replacing aging refrigerators and freezers with new Energy Star units could reduce energy use by at least a factor of 2. Fuel shifting means converting resistive loads (electric stoves, water heaters, space heaters, and clothes dryers) from electricity to propane. The direct conversion of propane fuel to heat is much more efficient than burning the fuel to generate electricity and then using electricity to create heat. So what does this mean for the existing operation at Brooks Camp? We estimate that incorporating these measures would reduce the electrical usage at Brooks Camp from 800 kWh/day to 250-300 kWh/day. If a properly sized engine generator were being used to meet this relatively constant demand load, we expect that the total seasonal load of 37,000 kWh would require less than 5000 gallons of diesel fuel.

The existing Brooks Camp facility has 27,017 sq. ft. of buildings. By incorporating our suggested energy reduction measures, the reduced energy requirement of 37,000 kWh would suggest that an energy use per unit area of 1.4 kWh/sq. ft. would be a good target for the new facility. Park plans (Ref. 4) indicate that the new facility would incorporate a significant expansion to 45,028 sq. ft. of buildings. Utilizing our energy metric, we believe the new facility should require approximately 62,000 kWh of seasonal electrical generation.

Summarizing, we recommend that the Park incorporate the following measures for building energy efficiency and load management at the new Brooks Camp facility:

- Use high efficiency fluorescent lighting,
- Incorporate daylighting, such as clerestories, in the building design,
- Enhance daylighting distribution such as light shelves and light ceiling surfaces,
- Utilize gas appliances for all thermal loads including space heating, water heating, clothes drying, and ovens/ranges,
- Use high efficiency (Energy Star) electrical appliances such as refrigerators and freezers,
- Incorporate load management such as soft motor starts and lockouts to preclude simultaneous motor starts; and schedule operations that require high electrical demand to times of otherwise low overall facility demand, and
- Initiate a culture among Park and concessionaire staff that emphasizes energy conservation, and develop a strong interpretive program of energy conservation for the visiting public.

Energy Generation

It is our understanding that the Park focus for the new Brooks Camp facility is to emphasize sustainable design and operation. We see the continued use of diesel fuel to be the greatest threat to this goal for energy generation and use. The transport of 3500 gallons of diesel fuel across pristine Naknek Lake offers a high risk of an environmental disaster. Information from Park staff describes their terrifying on-board experiences upon encountering 12 ft. waves on Naknek Lake while transporting a full barge load of diesel fuel to Brooks Camp. Considering the risk of a spill to the important red salmon spawning area of Naknek Lake and the potential impact on the bears that make Brooks Camp a world-class wildlife viewing experience, **we make the serious recommendation that the Park pursue propane as the fuel of choice for electrical and thermal energy generation at the new Camp.**

The use of propane-fueled engine generators at other NPS remote facilities is well established. All-propane energy generation exists at the following facilities, to name a few:

- Cottonwood, Joshua Tree National Park,
- Hozomeen, North Cascades National Park,

- Hole-in-the-Wall, Mojave National Preserve,
- Rogers Peak, Death Valley National Park,
- Hole-in-the-Wall, Sequoia/Kings Canyon National Park,
- Chaparral, Pinnacles National Monument, and
- Dangling Rope Marina, Glen Canyon National Recreation Area.

It's interesting to note that all of the above facilities also include photovoltaics (PV) as part of the facility power system. In fact, the Park justification for removing diesel fuel from Dangling Rope (a site with nearly identical daily energy use as Brooks Camp) was based entirely on the risk of a diesel spill on Lake Powell.

The conversion to all-propane-fueled energy generation at the new Brooks Camp offers the major advantage of nearly eliminating diesel transport to the site (it is expected that some small use for heavy equipment may be required). While we expect the cost of propane fuel to be higher than diesel, perhaps as much as a factor of two per gallon delivered to the site, the higher efficiency generation of energy, especially for thermal loads, will act to offset this cost increase. Probably the most dramatic savings with bulk propane usage involves the avoided cost of building the diesel fuel storage and delivery piping/pumping plant infrastructure at the new facility. This life-cycle savings alone could easily justify the conversion. Propane electrical generation also significantly reduces atmospheric emissions, essentially eliminating NO_x and SO_2 and reducing carbon emissions by nearly one-half, thereby saving most of the existing $43,000 yearly emission cost for diesel generation at Brooks Camp.

RENEWABLE ENERGY RESOURCE

We examined three possible sources of on-site renewable generation: (1) small hydro, (2) geothermal for ground source heat, and (3) solar – wind, PV, and solar hot water.

The hydro resource is based on the nearby Brooks River, prime fish habitat and a world-class bear viewing area. We see little or no opportunity of diverting river flow for hydro generation.

Discussions with Park staff confirm that there is no known geothermal resource at the site and any evaluation would likely entail significant disturbance of otherwise sensitive archeological areas. We were informed that the US Department of Energy had proposed working in some of Katmai's volcanic areas during the recent past and that Park policies for resource protection curtailed any such activities.

During our site visit, both at King Salmon and Brooks Camp, the sky conditions were generally overcast with low clouds and some rain, with little direct sun. Winds were very light, especially at Brooks Camp. Solar resource information for King Salmon (Ref. *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors*, National Renewable Energy Laboratory Report TP-463-5607, April 1994) shows solar availability to a flat plate collector at latitude tilt – 15 degrees of slightly more than 4 kWh/sq. m/day for the months of May, June and July, 3.6 kWh/sq. m/day in August, dropping to 3 kWh/sq. m/day in September. The direct normal component of the solar resource is less than half of the total resource. We evaluate the solar radiation resource as marginal for PV generation (compared to a typical summer resource in the sunny southwest of 7.5 to 8 kWh/sq. m/day) and poor for solar thermal applications.

The average wind speed (same solar radiation data reference as above) for King Salmon during these same months is approximately 4.7 meters/sec. (10.5 mph), also a marginal resource. Brooks Camp is significantly inland from King Salmon and the coastal wind patterns. Although no on-site wind data currently exists at Brooks Camp, an effort is underway within the Park to gather daily anemometer readings at the Camp. We do not anticipate that Brooks Camp has a significant wind resource but the question of wind generation at the site may prove to be moot. The exposure from the bluff of the new Camp site is to the northwest and the site is currently covered with a pine canopy of 40-50 feet. A determining factor in the Park's location of the new Camp site was that it not be visible from either the Brooks River or Naknek Lake. Discussions with Park staff lead us to believe that a minimum-height 90-ft wind tower(s), with the attendant noise and potential impact on birds, visibly situated on the Beaver Pond terrace bluff is not an aesthetically viable option to the Park.

Although there are no cooling loads at the new Camp, there is a substantial need for hot water to meet laundry, cooking, and bathroom/shower requirements. The modest solar resource at the site, primarily diffuse radiation, provides for limited use of PV for electrical generation but virtually eliminates solar thermal water heating as an option even without the solar access difficulties at the new site. We conclude that the only viable renewable technology applicable to the new Camp site is PV and the marginal solar resource coupled with our solar access concerns will limit its usefulness.

PHOTOVOLTAIC POWER OPPORTUNITIES

We have identified a number of possible PV applications that could contribute modestly to the energy needs of the new facility as well as other Park power needs in the nearby vicinity. Our proposed applications are prioritized below, with 1 being the highest priority.

1. A 5-kW grid-tied (or stand-alone) PV system installed on the southeast-facing roof of the lodge. At 10 percent efficiency, the array will cover approximately 500 sq. ft. of roof area and could be mounted at a slight offset, perhaps 4 inches above, and parallel, to the roof. The system will require a 5-kW inverter (suggested option is a Trace SW-5548) intertied directly to the electrical distribution system in the lodge. We estimate that the installed cost for the grid-tied system will be about $65,000 and could offset approximately 15 kWh per day of the Camp's energy needs from the engine generator. The primary benefit would be as a demonstration of renewable energy use and could be coupled with a computer-based information kiosk in the lodge for visitor interpretation. We recommend that the Park purchase two inverters, one as a back-up, to avoid significant downtime should the primary inverter require unscheduled maintenance. We have one technical concern for this option. The new engine generator must maintain operation between 58 and 62 hertz, which is required by the Trace inverter. If the frequency on the generator is outside these values, the inverter will shut down automatically and have to be manually restarted each time.

If you expect the tolerances to fall outside this range (or if the generator specification does not require 58 to 62 hertz), then we recommend that we reconfigure this 5-kW ac system to grid-independent, which will require the addition of batteries and a compatible inverter. The estimated cost of this variation is about $80,000. With this variation, a specific circuit of the lodge, for example the visitor center, would be powered by the PV system. We recommend that a manual transfer switch be added at the lodge service panel so that this electrical circuit can either operate off the Camp electrical grid or the PV system. This offers the added benefit that, if the grid is down, the circuit will still have power. In the case of a PV system outage, the circuit can still be powered off the Camp grid, adding maximum flexibility.

2. A stand-alone PV system to power the air pumps at the two diesel-spill remediation sites currently in operation at the existing Brooks Camp. After the Camp is relocated and the existing diesel generators are removed, the Park still requires power for these two sites on a continuing basis for the next 10 years. Each site has two pumps totaling 3-4 hp that run continuously for 4-hour time periods on an every-other-day scenario. The two sites do not operate simultaneously. We are unable to size the PV system at this time because of unknowns with the minimum power needs of the remediation pumping. However, the system will require a PV array, battery storage, and most likely an inverter. We propose that the system be mounted on the roof of the existing generator building, which will provide housing for the batteries and inverter. Power to the pump sites would utilize the existing power distribution network. Our main concern with this application is the potentially large array that may be required if the pump power and energy requirements and/or duty cycles aren't substantially reduced.

3. A small stand-alone PV system to power lights and fans at the campground service building. The small loads at this building, coupled with the opportunity to demonstrate PV technology compatibility with the wilderness camping experience, provides a good Park opportunity. The size of the dc system, which includes a small array, controller and batteries, cannot be determined until the dc lighting and ventilation requirements for the building are set. The array could be roof- or pole-mounted in an area with good solar access.

4. Small stand-alone PV systems for selected NPS Camp residences. Since the cooking, space heating, and water heating thermal loads in the residences will be met with propane, the electrical loads including lights, refrigerator, and small appliances should not exceed 4 to 5 kWh/day. A 1.5-kW array with batteries and an inverter would complete the system. Clear solar access for the roof- or pole-mounted array would be required. A manual transfer switch would allow the residence to operate either off-grid or on-grid with the facility power distribution system. We estimate that the installed power system would cost about $25,000.

5. Small stand-alone PV systems on selected concessionaire guest cabins. The only electrical need is power for lights. This application may appeal to the eco-tourism experience for Camp visitors. The array would be small, perhaps 300 watts or so, to provide perhaps one kWh/day, and could

be roof- or pole-mounted. A small battery bank and controller would complete the system. The lights would be dc. The estimated power system cost would be about $4500.

6. Small stand-alone PV system for historic building BL-3 at Brooks Lake facility. This would be an easy application for PV. Good solar access for a ground- or pole-mounted array is available. The electrical needs, if any, have not been defined so we are unable to estimate size or cost.

BATTERY AUGMENTATION OF ENGINE GENERATOR

Although this application does not necessarily incorporate PV, it is an option that will improve the power system efficiency and substantially contribute to the quality of life in the Camp, especially for those living near the engine generator building. As configured, a battery bank of deep cycle batteries coupled with an inverter would store energy from the engine generator during daytime charging. At night, perhaps after evening meal preparation, the engine would be turned off and left off until perhaps 7 am the next morning, enabling peaceful quiet throughout the Camp. The battery bank would carry the nighttime electrical load until the engine is restarted and the batteries would be recharged on a new daily cycle. This option allows the engine generator to operate near full capacity (and at maximum efficiency) during its operating time, since the total daily electrical needs for the Camp are being generated during a 12-hour (7 am to 7 pm) daytime period. Load management would absolutely be required to make sure that loads with large power demands and/or energy use (such as water pumps, effluent lift pumps, shop equipment, etc.) would only be scheduled during engine operation. Since maintenance on the engines is based on runtime, this option would reduce maintenance service and cost by a factor of 2 over continuous duty. On the other hand, the batteries and inverter would increase the power system cost.

For example, if the new Camp uses 460 kWh per day (our estimate of 62,000 kWh per the 135 day season) and meets this load with a 50-kW engine generator, the total daily load (including battery and inverter losses) could be generated during a 12-hour daytime period. This assumes the peak daytime demand is less than 50 kW. If the nighttime load was 100 kWh with a peak demand of 15 kW, one possible option would be to use a battery bank of 500 kWh rated capacity and a 15-kW inverter. Restricting the daily discharge to 20% or less of battery capacity will help prolong the battery bank's life. Our estimate for the installed cost of the batteries and two inverters (second inverter would provide back up in case of unscheduled maintenance for the primary unit) would be about $100,000. Some provision to house and protect the batteries from cold temperatures during the winter season would be required. It should be recognized that battery replacement, perhaps at 10-year intervals, will cost $50,000 with this option. Furthermore, the question of transport and recycling of batteries will need to be addressed. Load management during the daytime operating period becomes even more important to avoid peak demands that exceed the engine generator capability.

CONCLUSIONS

The Park has a unique opportunity to develop a showcase facility of sustainable energy practices. We have attempted to identify a number of options that can contribute to this effort, especially those that can reduce the need for energy and can meet the Park's needs with high-efficiency, low-environmental-impact power generation. Although renewables can only contribute modestly to this goal, we believe the incorporation of some PV at the new Camp will only strengthen the public's recognition that sustainable operation is not only the Park's future but the future of all parks across our country. We appreciate the opportunity to be involved in this endeavor and look forward to providing continuing assistance to the Park.