ANALYSIS OF ELECTRIC LOADS AND WIND- DIESEL ENERGY OPTIONS FOR REMOTE POWER STATIONS IN ALASKA

A Masters Project Presented

by

MIA M. DEVINE

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Feasibility Study 7: Kiana

Kiana is a village covering less than a quarter square mile of land on the north bank of the Kobuk River, 60 miles east of Kotzebue. The population is 400, 93% of which are Inupiat Eskimo. Kiana is located in the transitional climate zone with average temperatures ranging from –10° to 60°F. The state maintains a 3,400-foot lighted gravel runway in Kiana, and the Kobuk River is navigable from the end of May through early October, allowing the delivery of fuel and supplies. The primary means of local transportation include small boats, all-terrain vehicles, and snowmobiles (Department of Community and Economic Development, 2003).

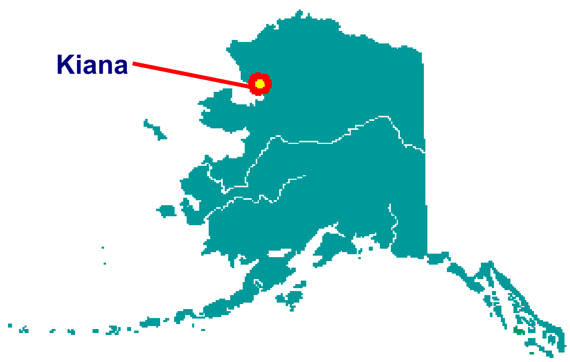

Figure 90. Location of Kiana, Alaska

Kiana is one of the more modern villages in the Northwest Arctic Borough. It was among the first communities in the region to construct a piped water and sewer system. The Maniilaq Association, a major year-round employer, operates a sub-regional health clinic in Kiana. Three general stores provide supplies brought upriver by boat. Seasonal employment is provided on river barges, fire-fighting, mining for jade or copper ore, and a growing tourism industry. Subsistence gathering of salmon, moose, caribou, waterfowl, and berries is also a major part of the local lifestyle and economy (Maniilaq Association, 2003). According to the 2000 U.S. Census, the unemployment rate is 12% and the median household income is $29,688.

Energy Use in Kiana

Kiana receives its electricity from a diesel power plant operated by the Alaska Village Electric Cooperative (AVEC). Data obtained from AVEC for the Kiana power station was analyzed to determine energy use trends. A breakdown of the electricity usage of the major consumer sectors is shown in Figure 91.

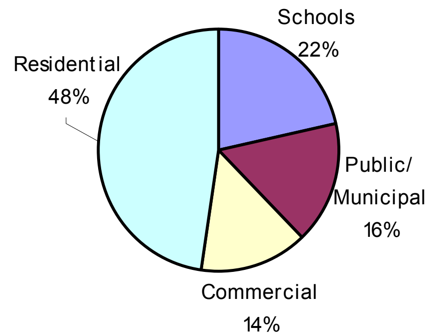

Figure 91. Major Energy Use Sectors in Kiana

Like most Alaskan villages, the residential sector is the largest consumer of electricity. According to the 2000 U.S. Census, there are 133 housing units in Kiana, with an average of 4.5 people per household. Most homes use fuel oil or kerosene for heat while about 7% of homes use wood fuel. Largest individual consumers of electricity include the school and water plant.

The characteristics of the public water system influence the amount of electricity it uses. At the Kiana water treatment facility a 200,000-gallon steel tank is filled intermittently from two water wells near the Kobuk River. The water is chlorinated before being distributed through buried water mains. A gravity sewer system drains to a lift station where wastewater is pumped to a sewage treatment lagoon northeast of the village. Piped water and sewer services are provided to about 75 homes, the health clinic, the school, and community hall. About 20 households are yet to be connected and haul water and use honeybuckets or septic tanks. The development of a public water system master plan, a new water treatment facility, and additional service connections have been funded.

Based on power plant production data collected by AVEC, a year of average hourly electric load data from the Kiana power station is shown in Figure 92. Like most Alaskan villages, there is a higher consumption of electricity in the winter than in the summer in Kiana. The diurnal load profile for an average day in each month is shown in Figure 93. These profiles were created by averaging each hour of each day within the month.

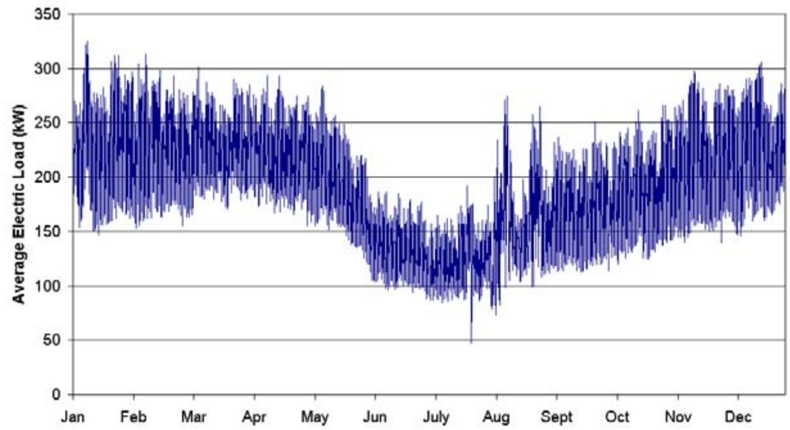

Figure 92. 2003 Hourly Electric Load in Kiana

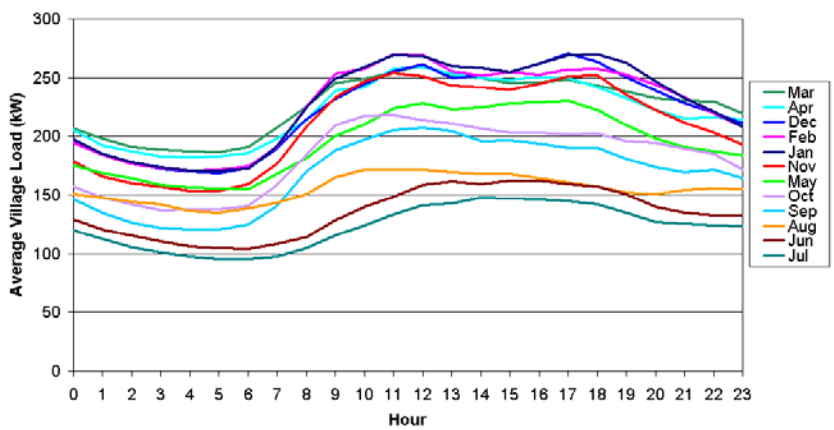

Figure 93. Diurnal Load Profiles for Each Month in Kiana

The load profile is more pronounced in the winter, with a sharp increase from 7:00AM to a peak around 12:00PM. The load is steady throughout mid-afternoon and peaks again in the early evening around 6PM. The electric and diesel fuel usage in Kiana since 1996 is summarized in Table 68. This information is also shown graphically in Figure 94.

Table 68. Summary of Energy Use in Kiana from 1996 – 2002

Year	Total kWh Generated	Average Load (kW)	Peak Load (kW)	Fuel Consumption (gal/yr)	Delivered cost of Fuel ($/gal)
1996	1,224,600	139	265	96,400	$1.65
1997	1,279,100	146	298	103,400	$1.53
1998	1,385,100	158	293	105,400	$1.26
1999	1,418,900	159	294	104,500	$1.33
2000	1,358,000	155	300	102,200	$1.60
2001	1,411,300	161	307	107,900	$1.75
2002	1,495,900	171	333	110,800	$1.73

The electric load in Kiana has been increasing at an average rate of 3.6% per year since 1996. The largest increase (8.2%) occurred from 1997 to 1998 when additional single-family housing units were constructed (Department of Community and Economic Development, 2004).

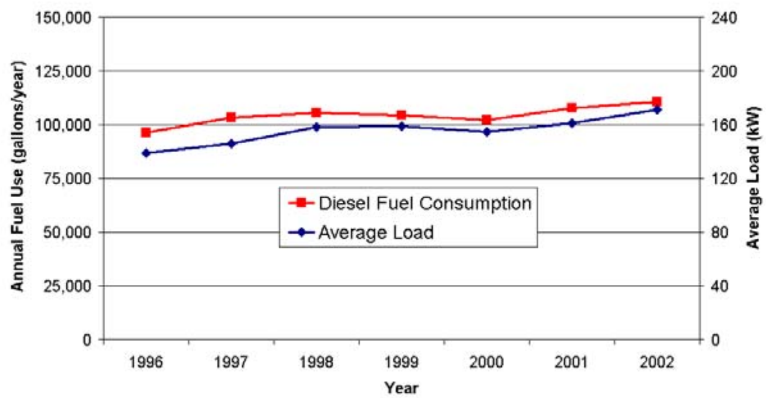

Figure 94. Energy Use from 1996-2002 in Kiana

For modeling purposes, the expected village load in 2009 will be used to evaluate the performance of potential a hybrid power system. A number of construction projects have been funded and are expected to be online by 2009. These projects include additional housing units, upgrades to the public water system, and possibly a multi-purpose building (Rural Alaska Project Identification and Delivery System, 2004). The 2003 electric load data in Kiana is adjusted to account for the addition of these facilities, based on the Alaska Village Electric Load Calculator method described in Chapter 1. The modified values are tabulated in Appendix 5, and a sensitivity analysis was performed around this parameter.

Existing Power Station in Kiana

The Kiana power plant includes four diesel generators totaling 1163 kW of rated capacity:

1) 314 Detroit Diesel Series 60 DDEC4
2) 350 kW Cummins KTA1150
3) 499 kW Cummins KTA19G4

Useable diesel storage capacity is 112,500 gallons, usually requiring 3 shipments of diesel fuel per year. The measured fuel curves for the diesel generators were obtained from AVEC and are shown in Appendix 4. The Cummins fuel curves are based on a Cummins model VTA-28G5. For modeling purposes, the minimum allowed power was specified at 30% of rated power.

Wind Resource in Kiana

Average hourly wind speeds from January 2003 through December 2003 were obtained from the Western Regional Climate Center online database. A Remote Automated Weather Station (RAWS) in Kiana recorded hourly wind speed information at a height of 20 feet. This station is located at the airport and is maintained by the Alaska Bureau of Land Management Fire Service Department (Shelley, 2004). The data recovery rate for the year was only 78%. Two weeks in January and most of November and December were missing. These gaps were filled using data from previous years. Shorter gaps in the data were filled using the Hybrid2 Gapfiller program (University of Massachusetts Renewable Energy Research Lab, 2004). The compiled year of hourly values was scaled to meet the long-term (1992-2003) average monthly wind speeds at the same location. The adjusted wind speed data set is shown in Figure 95 and summarized in Appendix 6.

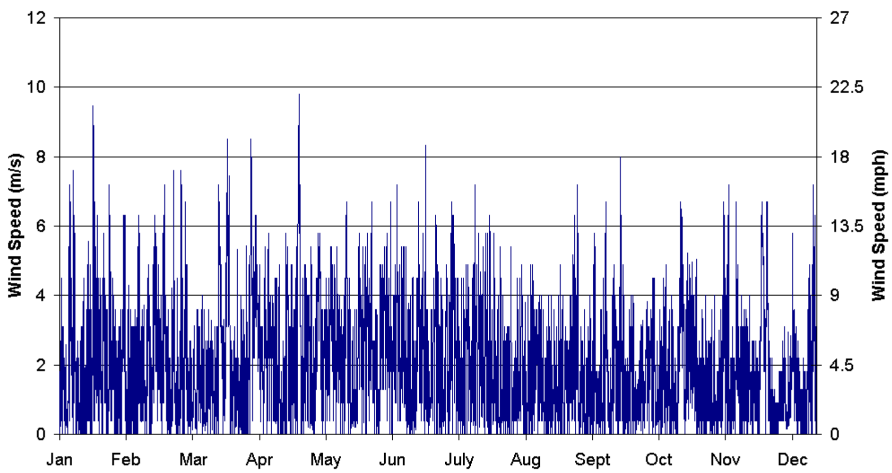

Figure 95. Hourly Wind Speeds Measured at 6.1-meter Height in Kiana

The annual average wind speed for the year is 2.4 m/s (5.4 mph) at a 6.1-meter height, 2.6 m/s (5.8 mph) at a 10-meter height, and 3 m/s (6.7 mph) at a typical hub height of 30-meters. The maximum average hourly wind speed recorded during the year was 10.2 m/s (22.8 mph) at a 6.1-meter height. A sensitivity analysis was conducted to account for the uncertainty of this data.

The seasonal and diurnal wind speed profiles are shown in Figure 96 and Figure 97, respectively.

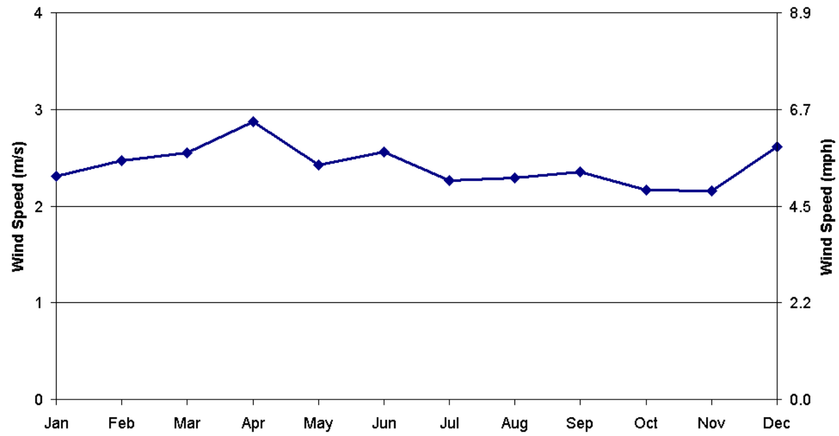

Figure 96. Seasonal Wind Speed Profile Measured at a 6.1-meter Height in Kiana

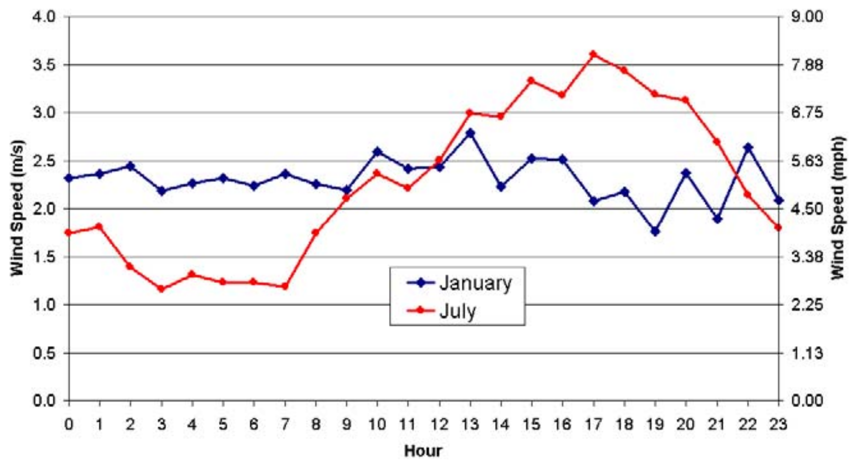

Figure 97. Diurnal Wind Speed Profile Measured at a 6.1-meter Height in Kiana

The wind rose in Figure 98 was created by determining the percent of time that the wind comes from a particular direction. It indicates that the prevailing wind direction is from the east and southwest quadrants.

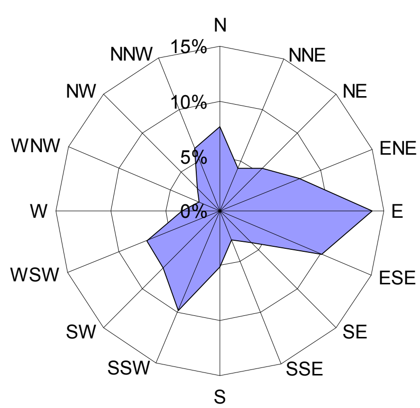

Figure 98. Annual Wind Frequency Rose for Kiana

The RAWS equipment is not a standard wind monitoring station for use in power production calculations; therefore, the wind resource used in this report is a conservative estimate and a sensitivity analysis is conducted to account for its uncertainty. The actual wind resource should be monitored at the proposed wind turbine location before the system design is finalized.

Power System Modeling Results for Kiana

To compare the design options of a hybrid power system in Kiana, the computer simulation model HOMER was used. HOMER uses hourly electric load data and hourly wind speed data to compare the ability of different types and quantities of wind turbines to meet the village load given the local wind resource. The characteristics of the diesel power station were modeled to determine the fuel consumption and cost of energy of the diesel-only system. Table 69 summarizes the expected performance of the power station, based on the estimated electric load data for the year 2009.

Table 69. Expected Energy Requirements in 2009 for Kiana

Total Energy Use	Peak Load	Average Load	Fuel Consumption	Net Present Cost
1,721,800 kWh/yr	411 kW	242 kW	140,000 gal/yr (530,000 liters/yr)	$6,273,200

A sensitivity analysis was performed on the cost of diesel fuel, which has the most impact on the cost of energy. The resulting cost of energy and the net present value of the system costs over the lifetime of the project are shown in Table 70.

Table 70. Cost of Energy for Diesel-Only System in Kiana

Diesel Fuel Cost	Cost of Energy	Net Present Cost
$1.50/gallon ($0.40/liter)	$0.14 /kWh	$5,073,500
$2.00/gallon ($0.53/liter)	$0.17 /kWh	$6,273,200
$2.50/gallon ($0.66/liter)	$0.22 /kWh	$7,473,000
$3.00/gallon ($0.79/liter)	$0.25 /kWh	$8,672,800

According to AVEC records, these diesel-related costs account for only about 40% of the total cost of electricity. The remainder includes other power generation expenses, such equipment and maintenance for the fuel tanks and transmission lines, administrative and general expenses, interest, and depreciation. However, these other expenses will still exist with a wind-diesel system. Therefore, the cost of energy listed in Table 70 is used to directly compare the diesel-related expenses with the wind-related expenses.

The impact of various numbers and types of wind turbines on fuel savings is shown graphically in Figure 99.

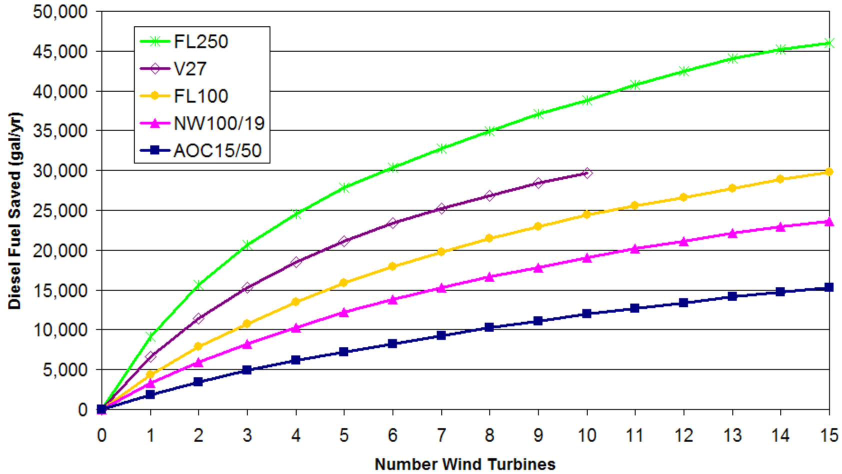

Figure 99. Effect of Different Wind Turbines on Diesel Fuel Savings in Kiana

Due to the poor wind resource measured in Kiana, the wind turbines do not produce as much electricity as they could if sited in a windier location. Capacity factors of the different wind turbine types, given Kiana's wind resource, are less than 25%. An economic evaluation of the different power options indicates that there are no wind-diesel systems that would result in a lower cost of energy or lower net present cost than the diesel-only system. An annual average wind speed of at least 5.4 m/s (12 mph) at a 10-meter height is needed in order to make a wind-diesel system in Kiana economically justified.

The draft wind resource map for Alaska suggests that Kiana lies within a Class 2 wind regime with an annual average wind speed of 6.3 m/s (14.1 mph) at a 10-meter height, and that there are areas near Kiana with a Class 6 wind regime (Heimiller, 2004). If a more exposed location than the airport can be found near Kiana to site the wind turbine(s), then the systems summarized in Table 71 would be recommended.

Table 71. Recommended System Configurations Assuming a 5.4 m/s Wind Speed in Kiana

Penetration Level	# of Wind Turbines				Initial Capital	Total Net Present Cost	COE ($/kWh)	Wind Penetration	Fuel Use (L)	Fuel Use (Gal)	Fuel Savings (Gal)
	FL250	AOC	NW100	V27							
Diesel-only					0	$6,273,200	$0.170	0%	530,000	140,026	0
Low			1		$550,000	$6,293,096	$0.171	13%	470,950	124,425	15,601
		1			$375,000	$6,319,869	$0.172	8%	491,674	129,901	10,126
		2			$640,000	$6,357,203	$0.173	15%	460,865	121,761	18,266
Medium	1				$930,000	$6,331,815	$0.172	35%	406315	107,349	32,678
High				2	$1,480,000	$6,284,805	$0.171	54%	355,130	93,826	46,201
	2				$1,860,000	$6,286,324	$0.171	70%	326043	86,141	53,886

Conclusions for Kiana Feasibility Study

The available wind resource data indicates that wind energy is not an economically feasible option in Kiana. A minimum annual average wind speed of 5.4 m/s at a 10-meter height (6.2 m/s at a typical wind turbine hub height of 30-meters) is required. The draft wind resource map for Alaska suggests that there are windier sites around Kiana where a wind power system could be located. If the wind speed at a more exposed site in Kiana is measured and results in an annual average wind speed of at least 5.4 m/s, the feasibility study should be repeated with the new data.