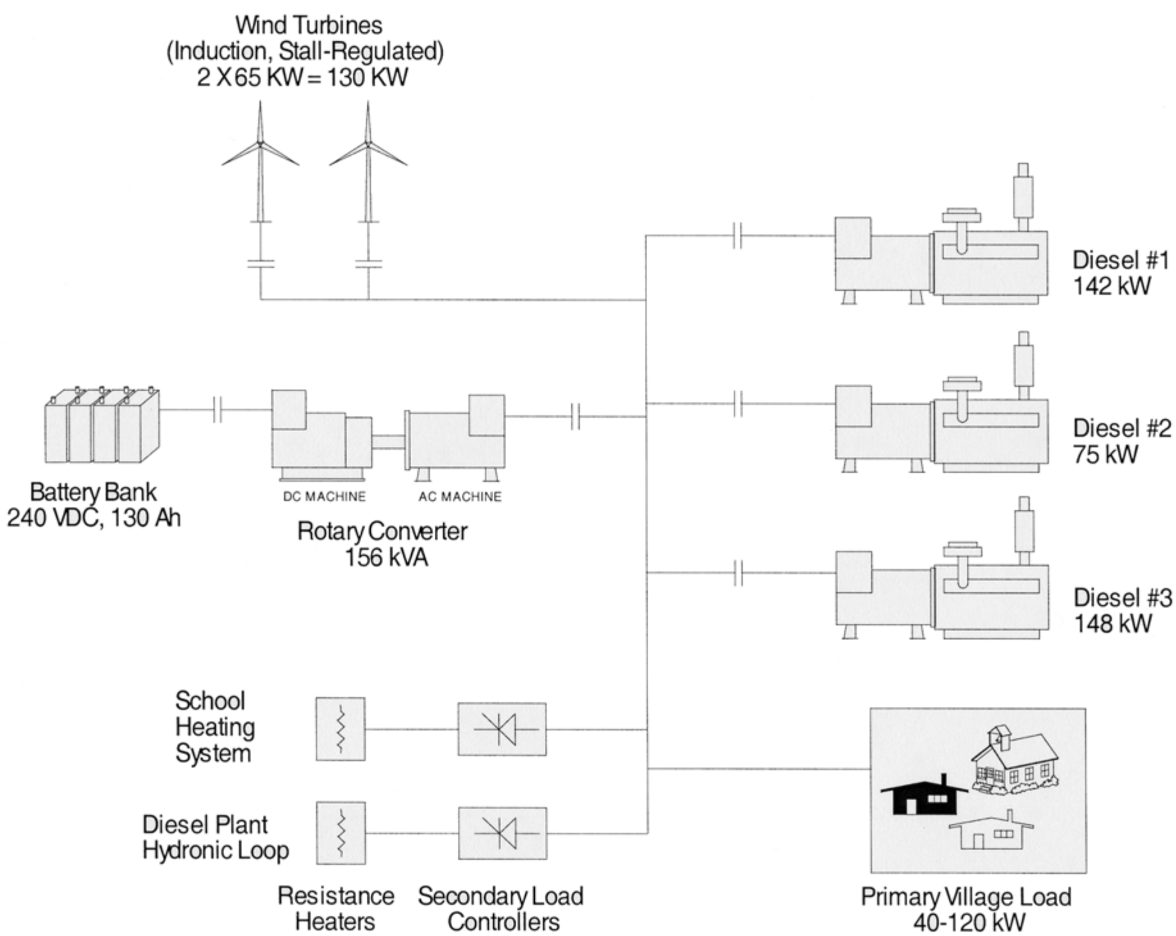
3.6.4.3 The Wales Project

Description

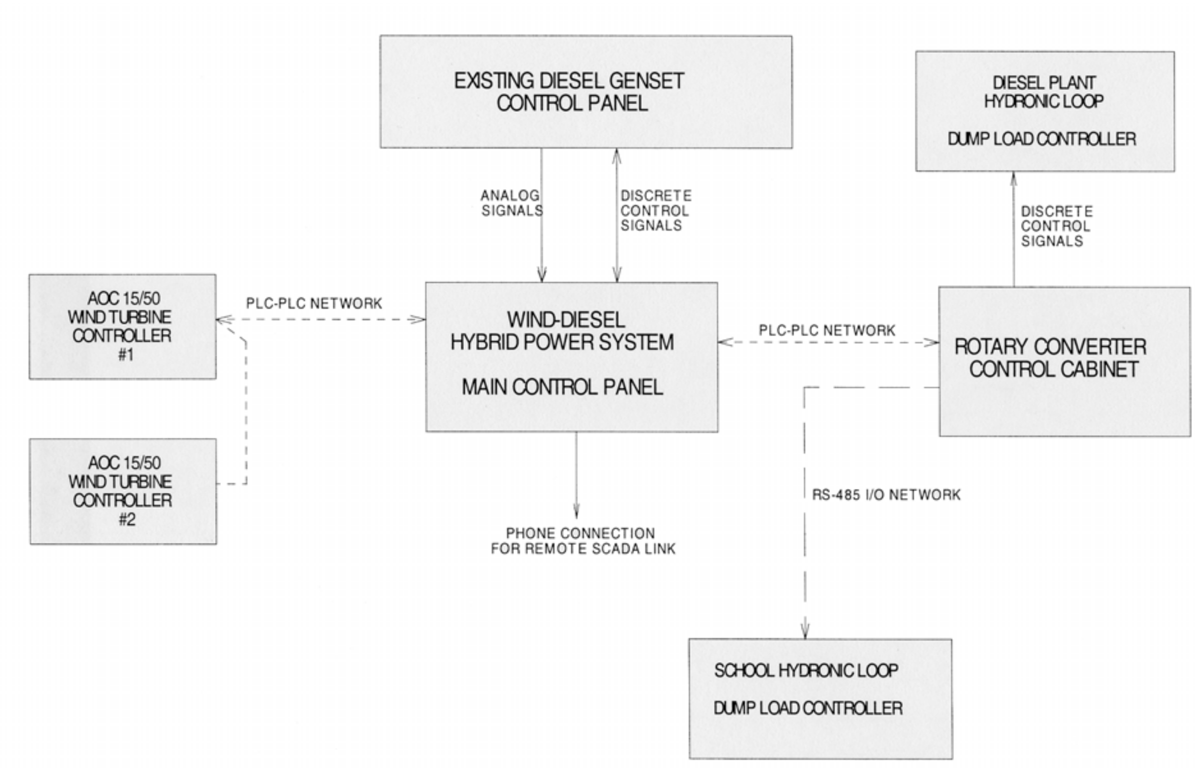
The Wales wind demonstration project is another high penetration system that has short-term energy storage. This is another village power system designed to support an average load of about 70 kW and an occasional peak load of about 140 kW. The Wales diesel power system consists of three diesel generator sets rated at 75 kW, 142 kW, and 148 kW. The system is manually controlled and essentially run as a single-diesel plant. The Wales wind-diesel hybrid power system consists of the diesel generator sets, two 65-kW wind turbines, a 156 kVA rotary power converter, a 31 kWh battery bank, and a 234 kW electric boiler secondary loads system controls. The estimated average annual penetration of the hybrid system is about 100 percent and the peak penetration was estimated at approximately 350 percent. This system is illustrated in Figures 3-10 and 3-11.

Figure 3-10. Wind Diesel System Architecture in Wales



Source: Wind System Options for Rural Alaska, AIDEA

Figure 3-11. Wales Wind Diesel System Communication and Control



Source: Power System Options for Rural Alaska, AIDEA

Participants in the wind project include NREL, AK Department of Community and Regional Affairs, KEA, and AVEC.

Performance and Reliability

At this time, there are no available official reports on the performance of the Wales hybrid system. Preliminary AIDEA (2001) reports indicate that the system has been in partial operation since October of 2000 due to some powerhouse problems. The sensitivity of the equipment to variability in wind generation and the age of the diesel generators have prevented the system to operate in wind-only mode (or in partial operation). AVEC intends to operate in fully-automated mode after an initial break-in period (Meiners, 2001)

Preliminary information contained in the wind diesel control panel shows data for the fifth and sixth month of operation.[111] The data indicate that wind penetration increased from 14 percent to 17 percent from June to July 2001, respectively. The diesel generators still support 86 percent and 83 percent of the load in June and July of 2001, respectively.

More recent unofficial reports indicate that the Wales wind turbines are covering a considerable portion of the electrical demand—during certain 48 hour periods in March wind turbines were almost able to completely displace diesel generation.

[111] This information was obtained from the Wales performance log sheet generated by the wind-diesel control panel. The information was received on March 8, 2002, from AIDEA.

Estimated System Costs of the Wales Project

The capital costs presented in Table 3-22 for the Wales project are based on a feasibility study conducted in 1997 by the National Renewable Energy Laboratory.

Table 3-22. Total Estimated System Costs of the Wales Project

Total System Costs	1997 Dollars
Wind Turbines (3)	270,000
Rotary Converter	55,000
Battery Bank (31.2 kWh)	43,500
Optional Load	50,000
Balance of System	118,000
Total Shipping (3 wind turbines)	83,000
Installation Overhead (5% of turbine, battery, and rotary converter)	4,150
Total Installed Cost	**610,650**

Source: Performance and Economic Analysis of the Addition of Wind Power to the Diesel Electric Generating Plant at Wales, AK. A preliminary report (unofficial NREL document).

Several modifications to the Wales system were made since the first month of operation. The cost of the system is therefore different from the initial estimates provided above. NEI has recently acquired a modified system cost breakdown. The costs include the following: 1) foundations ($146,000); 2) erecting ($65,000); 3) 3-PH conversion ($32,000); 4) battery storage unit ($150,000); 5) dumploads ($93,000); 6) system controller and diesel integration ($58,000); 7) general labor ($216,000); 8) travel and freight ($210,000); 9) Miscellaneous ($30,000). Total system capital costs amount to $1,067,000 or roughly $8200 per kW installed for a high penetration system with two 65kW wind turbines.

Assuming a 57.5 percent annual capacity factor (design value), with an actual installed cost of $8,200 per kW, the levelized cost per kWh is on the order of 19 cents per kWh. The estimated avoided costs are in the range of 12 to 20 cents per kWh (low to high in Wind Resource Reconnaissance Model). Thus, while the actual capital costs appear to be significantly higher than originally projected, the project may yet yield positive economic benefits.

3.6.4.4 Selawik Project

Description

The Selawik system was in an initial design phase at the first draft of this section. The project was subsequently shelved. The discussion that follows represents the system knowledge at the end of the third quarter of 2001.

This system is designed to be a simple, low-penetration system in which wind turbines are operated in parallel with an electronically controlled diesel generator set, without any energy storage or sophisticated control systems. The target wind penetration level is 25 to 30 percent. This project intends to test the upper level of wind turbine capacity that can be integrated smoothly with existing diesel equipment without changing current utility practices. The configuration of the system is not intended to drastically affect the design or operation of the existing utility (AVEC, 1999).

The system has a set of three wind turbines (rather than one large machine) so as to filter the power output fluctuations of the turbines, resulting in a more stable output and reduced size and frequency of changes in diesel engine speed. AVEC is looking into the Detroit Series 60 diesel generator set for potential retrofit for other communities. This type of generator set has proven to be highly fuel efficient under different loading conditions. The electronic controls designed into the Series 60 makes it possible for the addition of wind energy without requiring major equipment modifications, training, and changes in powerhouse management practices.

The AOC wind turbines have a manufacturer's rated capacity of 50 kilowatts at a wind speed of around 25 mph. At Kotzebue, the same AOC 15/50 units are rated 66 kW. The load in Selawik varies from a high of nearly 500 kW in winter to a minimum of 90 kW during summer nights. The problem in most hybrid systems is properly integrating the fluctuations in energy output from wind turbines into the system, especially in the short-term. When the load in Selawik peaks above 300 kW, the wind turbines could provide sufficient energy so that the less efficient generators [112] (the Caterpillar 3412's) are not brought on line.

Performance and Reliability

Since the system is not yet in operation, performance and reliability data do not exist.

Estimated Project Costs for the Selawik Project

The estimated capital costs for this system is based on a feasibility study of installation of 3 AOC 15/50 wind turbines (see Table 3-23).

Table 3-23. Estimated Project Costs for the Selawik Project

Cost Item	Description	Cost
Distribution system	4 pole, 12.5 kV, 3 phase, OH	$42,300
Turbine purchase	3 AOCs with village mods	$259,873
Turbine installation		
Foundations		$97,227
Turbines		$53,000
Power system modifications	Wiring, controls, engineering	$62,000
Support/Engineering expenses	Equipment, travel miscellaneous expenses	$25,600
Total project estimate		**$540,000**

Source: AVEC, 1999

The Selawik project was subsequently shelved.

3.6.4.5 High Wind Potential Sites

High wind resources are common in Alaska's coastal and offshore areas. The Aleutian Islands is the largest area of high wind power in the country. High wind resources are not limited to this area, but extend through most of the upper coastal area of Alaska. In the Beaufort and Chukchi Seas, coastal and offshore areas, wind power on the average is measured at class 5.[113] Most of the high wind areas in this northern region are confined to coastal areas, with a known exception south of the eastern Beaufort Sea to the Brooks Range. Most of the islands in the Bering Sea have class 7 wind power; the exception is St. Lawrence Island, which has class 6 wind power. Most coastal areas of the Bering Sea

112 The diesel engine fleet at Selawik include: Two 1200 rpm Caterpillar 3412 rated at 350 kWe each; One 1200 rpm Cummins KTA2300 rated at 557 kWe; and One 1800 rpm Dettroit Diesel Series 60 rated at 314 kWe.

113 Estimates of wind resources are typically expressed in wind power classes ranging from class 1 to class 7.

have class 5 or higher wind power. In the Yukon-Kuskokwim Delta, wind power of class 5 extends inland up to 150 kilometers. The entire Alaska Peninsula has wind power over class 5, with most areas west of 162°W longitude (between the cities of King Cove and Sand Point) having class 7. The Gulf of Alaska has varied wind power. Exposed areas and areas offshore tend to have wind power of 5 or above. Near shore terrain in much of the area lowers wind potential, making wind resources very site specific. The Lower Cook Inlet is also thought to have high wind power potential, primarily in the area from Iliamna Lake to Kamishak Bay. While the coastal wind resources are broadly available (with the notable exception of Southeast), wind power in inland Alaska varies greatly depending on the site. Many mountain ridges have wind power of three or greater. Wind power in these inland areas tends to be localized and is dependent on terrain and the exposure of an area to prevailing winds. See Appendix B for a list of communities with a wind resource of wind power class 4 or above from the NREL Wind Resource Reconnaissance Maps.

3.6.5 Potential Savings from Existing Technology Deployed

This section reviews the potential savings from the existing or planned wind resource developments in St. Paul, Kotzebue, Wales, and Selawik.

The economic benefits of wind hybrid systems are evaluated in this section based on the estimated avoided costs

1. fuel savings with and without storage for retrofits and new diesel generator sets;
2. reduction in variable generation O&M (wind-diesel hybrid overhauls *may be* less frequent than diesel only overhauls); and
3. fuel savings from the secondary loads (thermal energy).

The with and without storage cases refer to with diesel tank farm storage cost savings and without diesel tank farm storage cost savings, respectively. The cost estimates used were obtained from actual project reports, personal communication, and feasibility studies of the wind projects described in the previous section.

Listed in Table 3-24 are assumptions used in deriving the avoided costs. These assumptions are consistent with the assumptions used in other sections of the report.

Table 3-24. Assumptions Used in Estimating Avoided Costs of Different Hybrid Systems

Item	Units	Low	Medium	High
Fuel Price	$ per gal	1.12	1.25	1.6
Diesel Efficiency (Existing generator sets)	kWh sold per gal	10	11.5	13
Diesel Efficiency (New generator sets)	kWh sold per gal	11	12.5	14
Total Cost of Fuel + Storage	$ per gal	1.6	1.97	2.32
Generation + Transmission & Distribution (T&D)	$ per kWh	0.034	0.034	0.034
T&D Avoided Cost	$ per kWh	0.015	0.01	0.005
Generation-Only Avoided Cost	$ per kWh	0.019	0.024	0.029

Notes:

- The hybrid systems are not expected to generate avoided costs from transmission and distribution; the avoided cost from generation-only was used in the analysis.
- A range of fuel prices as well as diesel efficiencies for new generators and existing generators are provided for a low, medium, and high level. Typically, a large community faces lower fuel prices than a smaller and more remote community.

The avoided costs for retrofits [114] and new diesel generator sets are comprised of savings from fuel (with and without storage), diesel generation, and diesel variable generation O&M (see Table 3-25 and Table 3-26). Table 3-25 shows the savings incurred (or avoided costs) for each kilowatt-hour of diesel generated.

Table 3-25. Calculated Avoided Cost without Storage in Dollars per Kilowatt Hour ($/kWh)

1. Generation	0.019	0.024	0.029
2. Variable Generation O&M	0.015	0.015	0.015
3. Fuel w/o storage (existing generator sets)	0.112	0.109	0.123
4. Fuel w/o storage (new diesel generator)	0.102	0.100	0.114
Avoided Cost of Retrofits (1+2+3)	**0.146**	**0.148**	**0.167**
Avoided Cost of New Generator Sets (1+2+4)	**0.136**	**0.139**	**0.158**

Table 3-26. Calculated Avoided Cost with Storage in Dollars per Kilowatt Hour ($/kWh)

1. Generation	0.019	0.024	0.029
2. Variable Generation O&M	0.015	0.015	0.015
3. Fuel + Storage (existing generator sets)	0.16	0.171	0.178
4. Fuel + Storage (new)	0.145	0.158	0.166
Avoided Cost of Retrofits (1+2+3)	**0.194**	**0.210**	**0.222**
Avoided Cost of New Generators (1+2+4)	**0.179**	**0.197**	**0.210**

Note: Fuel prices, ranging from a low estimate to a high estimate were used based on the range of fuel prices in the Wind Resource Reconnaissance Model long term estimates.

The total avoided costs of the different hybrid systems in Alaska are shown in Table 3-27 and Table 3-28. The total avoided cost per hybrid system is a function of the amount of wind energy generated (weighted by its capacity factor) and the calculated value of avoided cost per kWh (see. Table 3-29). The analysis in this section does not take into account the potentially lowered efficiency of diesels in wind hybrid systems. A sensitivity analysis in the next section will address this issue.

[114] In a hybrid system, the existing diesel engines could be used but are retrofitted to incorporate the wind component in the system

Table 3-27. Total Avoided Cost without Storage for Retrofits and New Diesel Generator sets

Retrofits	Wind Energy (kWh)	Low	Medium	High
Kotzebue (10 AOC)	1,167,270	$170,421	$172,401	$195,024
Selawik	355,568	$51,913	$52,516	$59,407
Wales I: Electricity only	654,810	$95,602	$96,713	$109,404
Wales II: Electricity+Heat		$114,642	$117,963	$136,604
St. Paul I: Electrcity only	965,790	$141,005	$142,643	$161,361
St. Paul II: Electricity+Heat		$151,018	$153,818	$175,665
New Generator Sets				
Kotzebue (10 AOC)	1,167,270	$158,536	$162,251	$184,762
Selawik	355,568	$48,293	$49,424	$56,281
Wales I: Electricity only	654,810	$88,935	$91,019	$103,647
Wales II: Electricity+Heat		$107,975	$112,269	$130,847
St. Paul I: Electricity only	965,790	$131,172	$134,245	$152,871
St. Paul II: Electricity+Heat		$141,185	$145,420	$167,175

Table 3-28. Total Avoided Cost with Storage for Retrofits and New Diesel Generator sets

Retrofits	Wind Energy (kWh)	Low	Medium	High
Kotzebue (10 AOC)	1,167,270	$226,450	$245,482	$259,673
Selawik	355,568	$68,980	$74,778	$79,100
Wales I	654,810	$127,033	$137,709	$145,670
Wales II		146,073	$158,959	$172,870
St. Paul I	965,790	$187,363	$203,110	$214,851
St. Paul II		$197,376	$214,285	$229,155
New Generator Sets				
Kotzebue (10 AOC)	1,167,270	$209,472	$229,485	$244,793
Selawik	355,568	$63,808	$69,905	$74,568
Wales I	654,810	$117,509	$128,736	$137,323
Wales II		136,549	$149,986	$164,523
St. Paul I	965,790	$173,315	$189,874	$202,540
St. Paul II		$183,328	$201,049	$216,844

Both Wales and St. Paul have two entries in the tables above, representing avoided costs from electricity only (I) and from electricity and thermal energy savings (II). Both systems are high penetration systems with the ability to generate thermal energy from secondary loads. The feasibility study for Wales estimated the potential amount of fuel savings (17,000 gallons) from the secondary load. The fuel savings from the thermal load of the St. Paul system were based on actual savings realized on the first two years of operation (equal to 8,940 gallons of fuel per year).

The avoided costs were estimated by calculating the wind energy produced per kilowatt-hour of the different hybrid configurations/systems using capacity ratings and capacity factors, as follows:

Table 3-29. Wind Energy (kW) Generated

Configuration/System	Capacity	Capacity Factor	Wind Energy (kW)	Annual (kWh)
St. Paul	225	0.49	110	965,790
Wales	130	0.575	75	654,810
Selawik	198	0.205	41	355,568
Kotzebue	650	0.205	133	1,167,270

Notes:

- The capacity of the wind component in the different systems ranges from 65 to 225 per wind turbine. There were inconsistencies in the way the system proponents measured capacity. The AOC turbines are rated 50, 65, and 66 kW in different reports.
- The capacity factors for Kotzebue and St. Paul are based on actual performance monitoring for the first few years of operation. The capacity factor for Wales is based on estimates from the feasibility study. For Selawik, the capacity factor of the Kotzebue system was used since their turbine configurations are similar.

To determine the net potential savings from the hybrid systems, the estimated avoided costs are compared to the added costs of developing a new wind hybrid system or integrating a wind system into existing diesel systems. Table 3-30 shows the total added costs of the different hybrid systems. The added costs of the hybrid systems include the total capital costs of equipment, installation (or balance of station costs), an additional amount worth $10,000 for maintenance training for the high penetration systems (St. Paul and Wales), and estimated annual operations and maintenance costs. The total capital costs were annualized assuming different discount rates (5 percent, 8 percent, and 12 percent) for a 15-year period.

Table 3-30. Total Added Costs of Hybrid Systems in Alaska

Hybrid Systems	Turbines	Penetration	Total Capital Costs	Annual Capital Costs			Annual O&M	Total Annual Added Costs		
				5%	8%	12%		5%	8%	12%
Kotzebue Phase I	3 AOC 15/50	Low	$591,000	$56,938	$69,046	$86,773	$7,875	$64,813	$76,921	$94,648
Kotzebue (All Phases)	10 AOC 15/50		$942,965	$90,847	$110,166	$138,450	$26,250	$117,097	$136,416	$164,700
Kotzebue (ISER estimates)	7 AOC 15/50		$1,020,000	$98,269	$119,166	$174,437	$10,000	$108,269	$129,166	$184,437
Selawik	3 AOC 15/50	Low	$540,000	$52,025	$63,088	$79,285	$7,875	$59,900	$70,963	$87,160
Wales	3 AOC 15/50	High+Thermal	$620,650	$59,795	$72,510	$91,126	$31,500	$91,295	$104,010	$122,626
St. Paul	Vestas 225	High+Thermal	$815,500	$78,567	$95,274	$119,735	$63,000	$141,567	$158,274	$182,735

Notes:

Three different estimated capital costs were used for the Kotzebue system— 1) the actual total capital costs for Phase I (3 turbines) as reported in the KEA Wind Power Economic Evaluation; 2) estimated capital costs for *all phases* (10 turbines) using Phase 1 costs and adding equipment costs for seven more turbines and a balance of station costs that represent an estimated 41 percent reduction in per unit costs; and 3) ISER estimates were based on Phases 2&3 capital cost estimates (NEI requested but was unable to obtain actual cost estimates for Phases 2 and 3 from KEA).

The estimated O&M costs for Kotzebue were obtained from the KEA report.
The estimated O&M costs for Selawik and Wales were based on feasibility studies.
The estimated O&M costs for St. Paul were obtained from personal communication with a TDX representative (Bruce Levy).
Included in O&M costs is a 5 percent contingency.

3.6.6 Potential Net Benefits and Likely Market Penetration Absent Intervention

Comparing the net present value of the stream of savings or benefits (avoided costs) with the added costs for each system, determines whether the wind hybrid system is cost-effective. Table 3-31 shows which of the systems have potential net benefits or losses, across different scenarios (or assumptions).

Table 3-31. Net Present Values of the Different Hybrid Systems

	Low		Medium		High	
	5%	15%	5%	15%	5%	15%
KOTZEBUE						
Without Storage						
Retrofits	$527,128	-$86,906	$546,694	-$76,842	$770,333	$38,190
New Generator Sets	$409,641	-$147,337	$446,356	-$128,452	$668,892	-$13,988
With Storage						
Retrofits	$1,080,996	$197,983	$1,269,131	$294,752	$1,409,412	$366,907
New Generator Sets	$913,158	$111,653	$1,110,998	$213,414	$1,262,322	$291,250
SELAWIK						
Without Storage						
Retrofits	-$78,953	-$245,647	-$72,993	-$242,581	-$4,869	-$207,541
New Generator Sets	-$114,742	-$264,055	-$103,558	-$258,302	-$35,770	-$223,435
With Storage						
Retrofits	$89,764	-$158,865	$147,072	-$129,388	$189,804	-$107,408
New Generator Sets	$38,637	-$185,163	$98,902	-$154,164	$144,998	-$130,454
WALES II						
Without Storage						
Retrofits	$230,798	-$116,945	$263,621	-$100,062	$447,895	-$5,278
New Generator Sets	$164,891	-$150,845	$207,334	-$129,014	$390,989	-$34,549
With Storage						
Retrofits	$541,505	$42,871	$668,890	$108,393	$806,403	$179,124
New Generator Sets	$447,351	-$5,558	$580,181	$62,765	$723,889	$136,682
ST. PAUL II						
Without Storage						
Retrofits	$93,427	-$261,587	$121,104	-$247,351	$337,073	-$136,265
New Generator Sets	-$3,781	-$311,587	$38,085	-$290,053	$253,141	-$179,436
With Storage						
Retrofits	$551,693	-$25873	$718,843	$60,103	$865,841	$135,714
New Generator Sets	$412,824	-$97,301	$588,004	-$7,195	$744,141	$73,115

Notes:
Low, medium, and high scenarios represent low ($1.12/gal), medium ($1.25/gal), and high ($1.60/gal) fuel prices.
Without storage scenario represents the case when there are no diesel tank farm cost savings.
With storage scenario represents the case when diesel tank farm cost savings are included.
Retrofits refer to the use of existing diesel generators with lower efficiency.
New generator sets refer to use of new generators with higher efficiency.
Wales II and St. Paul II refer to the case where both electric and thermal energy are generated.
Five percent and fifteen percent refer to the discount rates used in the net present value calculations. A five percent real discount rate may be appropriate for government funds or a government-owned utility, while a fifteen percent real discount rate may be appropriate for a risk adverse privately owned utility that incorporates a project risk adjustment into its discount rate rather than its cash flow analysis.
A 15-year project life was assumed.

Figure 3-12. Net Present Values: With Cost Savings from Storage, 5 percent Discount Rate

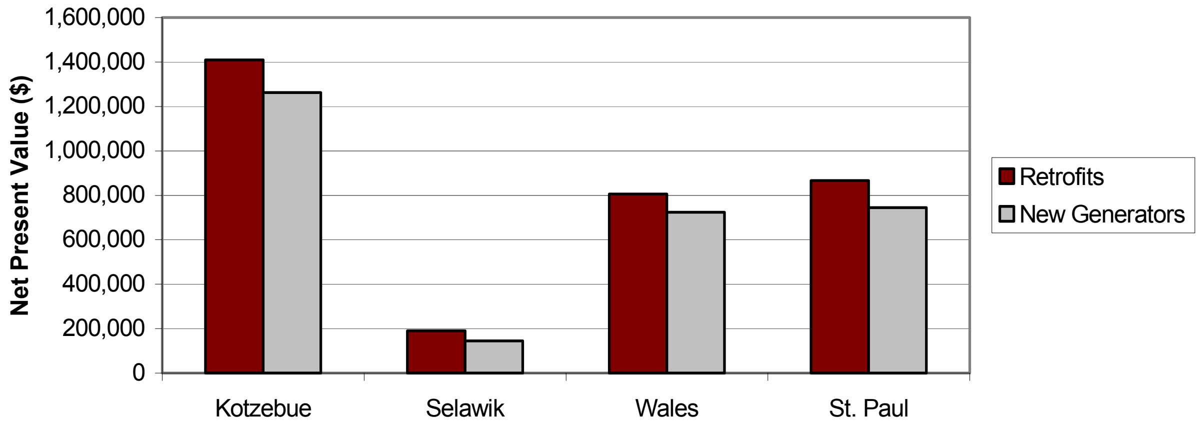


Figure 3-13. Net Present Values: With Cost Savings from Storage, 15 percent Discount Rate

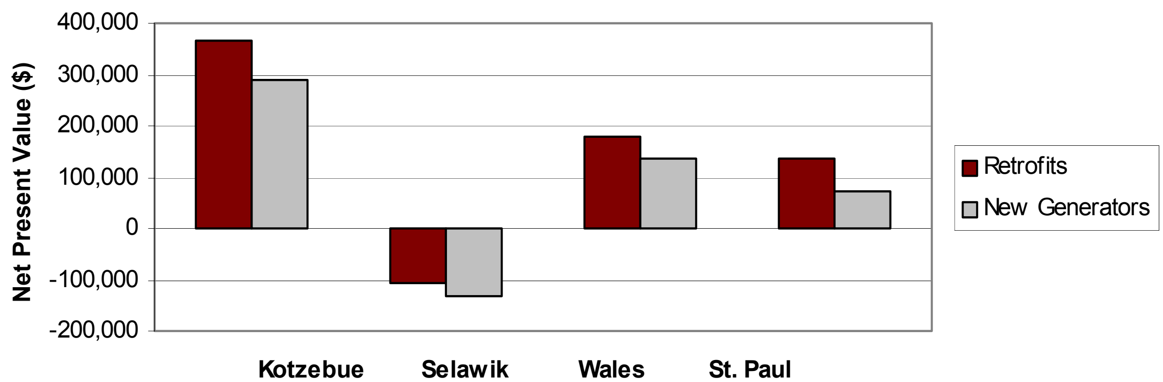


Figure 3-14. Net Present Values: Without Storage, 5 percent Discount Rate

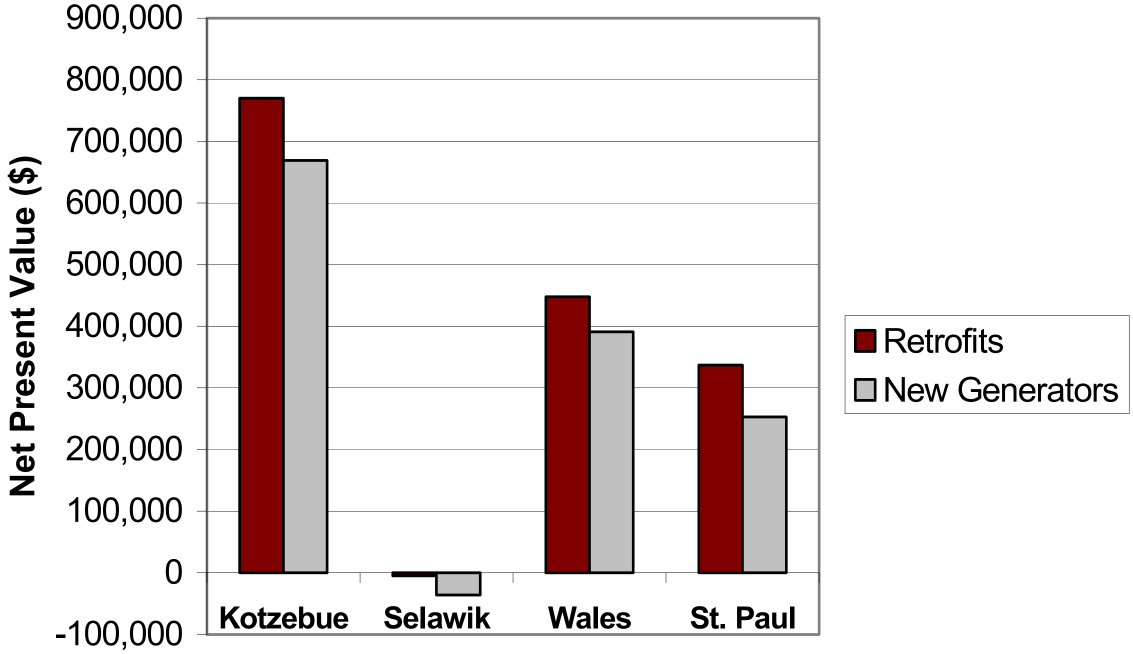
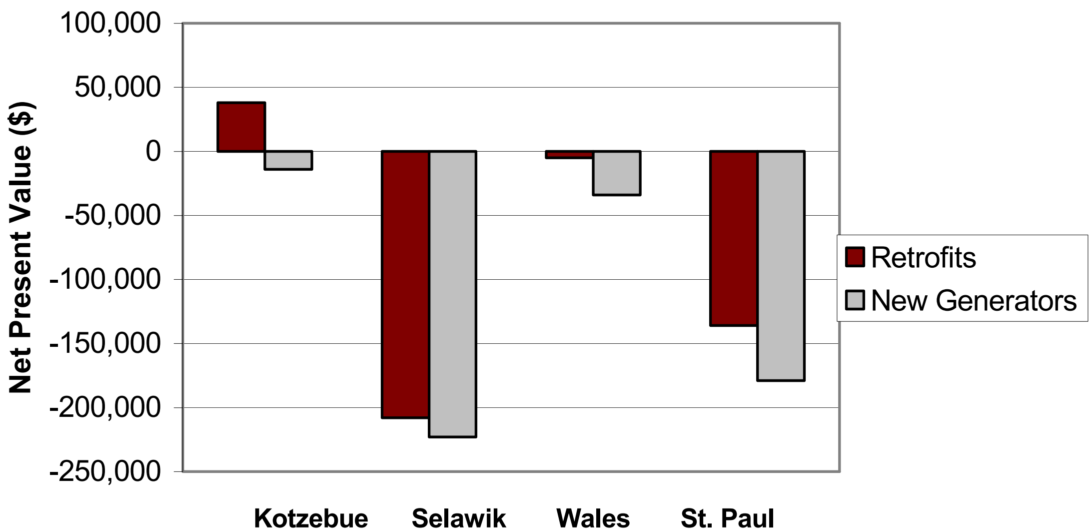


Figure 3-15. Net Present Values: Without Storage, 15 percent Discount Rate



Figures 3-12 to 3-15 show the net present values for the different wind systems under the high fuel price ($1.60 per gallon) scenario that is representative of some rural communities in Alaska. The Figures illustrate how assumptions concerning cost savings from storage and discount rates affect the net present values for the different wind system configurations. The wind system economics are sensitive to the discount rate used. A retrofitted system in Kotzebue is the only case showing a positive net return under the 15 percent discount rate (without storage). The results for Selawik show negative net benefits if the avoided cost of storage is not included even with the lower discount rate. This type of system is only viable when savings from fuel storage (in tank farms) are incorporated. This scenario may be appropriate for many small, remote villages where the cost of fuel and fuel storage are high.

The results (as shown in Table 3-31) indicate that the types/configurations of hybrid systems deployed in Alaska are viable under certain conditions. The viability of the systems is highly dependent on the discount rates used. The results show negative (discounted) net benefits for most systems with a discount rate of 15 percent, while many systems appear to yield a positive benefit/cost ratio with a discount rate of 5 percent.

The results indicate that for a system such as Kotzebue, the net benefits are high (both with and without fuel storage savings) at the five percent rate. At the 15 percent discount rate, only the case when fuel storage costs are included are the net benefits positive. The Kotzebue system is able to realize significant cost savings because of its large generation capacity.

For high penetration systems like Wales and St. Paul, the ability to produce more wind energy and to capture excess wind energy for secondary loads make it possible to realize higher net benefits relative to systems with comparable wind energy capacity but with low penetration. The benefits resulting from the secondary load being used for space heating are noteworthy. However, the higher capital and operating costs of high penetration systems may offset the potential benefits.

Except for the St. Paul project, all of the wind energy projects in Alaska have or had external support from the Department of Energy, the National Renewable Energy Laboratory, and the Alaska Energy Authority. The St. Paul project was privately funded by the Tanadgusix Corporation (TDX). TDX owns the facility that is supported by the wind hybrid system.

The market penetration of hybrid systems such as the ones described in this report is likely to be slow because the capital and initial operations and maintenance costs appear high relative to diesel systems and appear to pose a risk to individual utilities. Market penetration will likely be limited to projects that receive government support in order to reduce the project's risk adjusted cost of capital to the equivalent of a real discount rate of 5 percent. TDX has stated that it is exploring a high penetration system in Sand Point.

Sensitivity Analysis

A sensitivity analysis was conducted to address the issue of potentially reduced efficiency of diesel generators while operating under lower load levels in hybrid systems. Detailed information on diesel efficiencies under these conditions was not found, so as a proxy, the avoided costs from diesel generation O&M were taken out of the calculations and net benefits were recalculated (see Table 3-32). The results show that without cost savings from generation, the discounted net benefits of the different systems are reduced. The St. Paul system seems to be especially sensitive to the change in this variable, showing negative discounted benefits for all scenarios without storage at 5 percent and 15 percent discount rates. Without actual data on changes in diesel efficiency in wind-diesel hybrid systems, however, it is difficult to generate any concrete conclusions.

Table 3-32. Net Present Values of the Different Systems (without avoided costs from diesel generation)

	Low		Medium		High	
	5%	15%	5%	15%	5%	15%
KOTZEBUE						
Without Storage						
Retrofits	$307,889	-$199,674	$269,760	-$219,286	$435,705	-$133,931
New Generator Sets	$190,402	-$260,105	$169,422	-$270,896	$334,264	-$186,108
With Storage						
Retrofits	$861,757	$85,215	$992,197	$152,308	$1,074,783	$194,787
New Generator Sets	$693,918	-$1,115	$834,064	$70,970	$927,694	$119,130
SELAWIK						
Without Storage						
Retrofits	-$145,737	-$279,998	-$157,351	-$285,972	-$106,802	-$259,971
New Generator Sets	-$181,525	-$298,406	-$187,916	-$301,693	-$137,703	-$275,865
With Storage						
Retrofits	$22,980	-$193,216	$62,714	-$172,778	$87,871	-$159,839
New Generator Sets	-$28,146	-$219,514	$14,544	-$197,555	$43,065	-$182,885
WALES II						
Without Storage						
Retrofits	$107,810	-$180,205	$108,268	-$179,970	$260,177	-$101,834
New Generator Sets	$41,903	-$214,105	$51,980	-$208,922	$203,271	-$131,104
With Storage						
Retrofits	$418,517	-$20,389	$513,537	$28,485	$618,684	$82,569
New Generator Sets	$324,363	-$68,818	$424,828	-$17,143	$536,170	$40,127
ST. PAUL II						
Without Storage						
Retrofits	-$87,970	-$354,891	-$108,029	-$365,208	$60,204	-$278,676
New Generator Sets	-$185,178	-$404,891	-$191,048	-$407,910	-$23,728	-$321,847
With Storage						
Retrofits	$370,296	-$119,176	$489,710	-$57,754	$588,972	-$6,697
New Generator Sets	$231,427	-$190,605	$358,871	-$125,053	$467,272	-$69,296

3.6.7 Market Penetration Considerations

Local utilities are not likely to venture into wind hybrid systems without incentives or external support to reduce their individual risk. The barriers to market development include: high capital costs, uncertainty in wind resources, and the need for more experience beyond the pilot or demonstration phase.

The major limiting factor in the commercialization of these systems is the high capital costs required to transport, install, and operate wind turbines. Substantial cost savings, however, can be realized with multiple projects or larger systems. The cost estimates for Phases II and III of the Kotzebue system assume a 40 percent reduction in balance of station costs as a result of savings in engineering, construction and logistics costs (cost reductions increase with the number of wind systems installed) (GEC, 2000).

A new wind project is being conceptualized with 17 turbines that are expected to generate 2.98 MW per year at an estimated cost of $3.6 million. This system is anticipated to be built in Gambell because of its 7.0 wind power class and to possibly realize some cost savings from existing AVEC resources in Wales.[115]

Currently, all of the wind projects in the State, with the exception of the St. Paul project have been funded at least in part through Federal grants.

3.7 Appendices

Appendix A

Highly Attractive Wind Opportunities in Rural Alaska

Appendix B

Wind Power in selected Rural Alaskan Communities

Appendix C

Low Sulfur Fuel Requirements – Potential Price of Fuel Implications

Appendix D

Texas Deliberative Polling Renewable Energy Results

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Potentially Attractive Wind Opportunities in Rural Alaska

Appendix F

Simplified Break-Even Analysis

[115] Note that Gambell appears to have a B/C ratio of 1.4 in the Wind Reconnaissance Model under the medium penetration case.

3.8 Appendix A: Highly Attractive Wind Opportunities in Rural Alaska

	Utility/Community		Population	Total kwh Sold (kwh)	Total Fuel Used (gallons)	Average Long Run Price of Fuel ($/gallon)	kwh Sold per Gallon of Fuel Used (kwh/gallon)	Total Avoided Cost ($/kWh)	Wind Power Class	Wind Power Total Benefits (PV $ Life)	Wind System Total Costs (PV $ Life)	Benefit Cost Ratio (B/C)
	Highly Attractive Candidates											
1	St.Paul Municipal Electric Utility		673	**3,651,224**	**304,394**	$1.74	12.0	$0.17	7	$2,999,207	$1,736,894	1.73
2	Andreanof Electric Corporation (Atka)		105	310,556	33,920	$1.64	9.2	$0.22	7	$550,296	$326,113	1.69
3	Pedro Bay Village Council		36	154,367	22,160	$1.91	7.0	$0.34	4	$504,504	$317,319	1.59
4	Platinum, City of		43	118,496	20,111	$2.11	5.9	$0.43	5	$496,160	$314,400	1.58
5	Ipnatchiaq Electric Company (Deering)	(18)	148	1,246,308	123,876	$2.02	10.1	$0.24	5	$1,239,215	$799,781	1.55
6	Naterkaq Light Plant (Chefornak)		416	512,076	66,915	$1.34	7.7	$0.19	7	$473,785	$325,063	1.46
7	Gambell		668	1,820,552	165,218	$1.39	11.0	$0.15	7	$1,151,536	$817,697	1.41
8	False Pass Electric Association	(18)	68	323,290	39,609	$1.05	8.2	$0.18	7	$438,825	$324,611	1.35
9	Akutan Electric Utility		408	423,037	40,770	$1.45	10.1	$0.18	7	$437,244	$324,514	1.35
10	Nightmute		230	414,942	40,222	$1.39	10.3	$0.17	7	$420,263	$324,281	1.30
11	Kipnuk Light Plant		573	1,469,518	127,034	$1.26	11.6	$0.14	7	$1,021,549	$815,891	1.25
12	Kwig Power Company (Kwigillingok)		360	497,611	51,552	$1.24	9.7	$0.16	7	$401,829	$324,041	1.24
13	Puvurnaq Power Company (Kongiganak)		348	657,193	71,834	$1.49	9.1	$0.20	6	$394,250	$319,830	1.23
14	Hooper Bay		1,028	**2,228,231**	**195,962**	$1.18	11.4	$0.13	7	$1,284,827	$1,052,828	1.22
15	Perryville, City of		102	393,712	42,258	$1.64	9.3	$0.22	5	$376,719	$317,304	1.19
16	Savoonga		653	1,544,650	138,921	$1.39	11.1	$0.15	6	$1,222,002	$1,035,531	1.18
17	Wales		170	494,885	43,219	$1.36	11.5	$0.15	7	$382,008	$323,732	1.18
18	Nunapitchuk		471	945,192	178,809	$1.26	5.3	$0.14	6	$1,444,802	$1,260,358	1.15
19	Chevak		763	1,515,887	125,552	$1.19	12.1	$0.12	7	$928,455	$814,585	1.14
20	Toksook Bay		513	1,078,573	98,650	$1.31	10.9	$0.13	7	$673,775	$594,993	1.13
21	Kokhanok Village Council		163	274,953	25,426	$2.09	10.8	$0.23	4	$348,507	$315,045	1.11
22	Akiachak Native Communtiy Electric Co.		560	1,037,902	99,908	$1.68	10.4	$0.19	4	$872,608	$789,210	1.11
23	Point Lay		217	**2,801,232**	**249,956**	$1.11	11.2	$0.13	6	$1,853,265	$1,692,643	1.09
24	Kwethluk, Inc.		714	1,009,606	94,477	$1.72	10.7	$0.19	4	$859,661	$789,011	1.09
25	Mekoryuk		193	716,777	57,901	$1.31	12.4	$0.14	7	$344,587	$323,200	1.07
26	St. George Municipal Electric Utility		173	905,677	16,028	$1.64	12.0	$0.17	7	$326,586	$318,105	1.03
27	Brevig		279	580,099	48,447	$1.40	12.0	$0.13	7	$330,412	$322,980	1.02
28	Unalaska Electric Utility		4,178	**28,327,078**	**2,161,606**	$1.10	14.4	$0.09	7	$15,595,178	$15,375,554	1.01
29	Tununak		331	730,254	66,680	$1.26	11.0	$0.13	7	$325,808	$322,938	1.01
30	Eggik Light & Power Company		117	762,971	71,556	$1.40	10.7	$0.17	5	$583,940	$581,032	1.01
31	Atmautluak Joint Utilities		296	560,751	53,608	$1.33	10.5	$0.16	6	$319,491	$318,773	1.00
	Subtotal - Highly Attractive Candidates		14,997	57,507,600	4,876,579					38,601,294	33,618,254	1.15

3.9 Appendix B: Wind Power in selected Rural Alaskan Communities

Table 3-33. Minimum, Maximum, and Average Wind Power Classes of Selected Communities in Rural Alaska

Community	Area (sq. km)	Min. WPC	Max WPC	Avg. WPC
Akhiok	19	7	7	7.0
Akutan	48	7	7	7.0
Atka	256	7	7	7.0
Belkofski	6	7	7	7.0
Brevig Mission	11	7	7	7.0
Chefornak	96	7	7	7.0
Chevak	4	7	7	7.0
False Pass	44	7	7	7.0
Gambell	15	7	7	7.0
Hooper Bay	23	7	7	7.0
Inalik	6	7	7	7.0
Kaktovik	1	7	7	7.0
King Cove	14	7	7	7.0
Kipnuk	74	7	7	7.0
Kwigillingok	31	7	7	7.0
Mekoryuk	8	7	7	7.0
Newtok	24	7	7	7.0
Nightmute	264	7	7	7.0
Nikolski	303	7	7	7.0
Paimiut	72	7	7	7.0
St. George	57	7	7	7.0
St. Paul	87	7	7	7.0
Toksook Bay	83	7	7	7.0
Tununak	11	7	7	7.0
Unalaska	50	7	7	7.0
Wales	6	7	7	7.0
Nelson Lagoon	637	5	7	6.7
Point Lay	42	6	7	6.2
Atmautluak	3	6	6	6.0
Kasigluk	49	6	6	6.0
Kongiganak	28	6	6	6.0
Kotzebue	76	6	6	6.0
Nunapitchuk	18	6	6	6.0
Savoonga	17	6	6	6.0
Tuntutuliak	69	6	6	6.0
Platinum	106	5	6	5.8
Alakanuk	105	5	5	5.0
Chignik	40	5	5	5.0
Chignik Lagoon	28	5	5	5.0

Community	Area (sq. km)	Min. WPC	Max WPC	Avg. WPC
Chignik Lake	57	5	5	5.0
Chulloonawick	54	5	5	5.0
Deering	13	5	5	5.0
Egegik	173	5	5	5.0
Emmonak	18	5	5	5.0
Goodnews Bay	12	5	5	5.0
Ivanof Bay	28	5	5	5.0
Kake	21	5	5	5.0
Karluk	127	5	5	5.0
Koyuk	9	5	5	5.0
Perryville	91	5	5	5.0
Pilot Point	203	5	5	5.0
Port Heiden	119	5	5	5.0
Quinhagak	15	5	5	5.0
Sand Point	20	5	5	5.0
Sheldon Point	44	5	5	5.0
Wainwright	16	5	5	5.0
Ugashik	246	4	5	4.7
Larsen Bay	20	4	5	4.6
Napakiak	14	4	6	4.4
Akiachak	73	4	4	4.0
Akiak	6	4	4	4.0
Annette Islands	301	4	4	4.0
Bethel	127	4	4	4.0
Iliamna	64	4	4	4.0
Kasaan	10	4	4	4.0
King Salmon	613	4	4	4.0
Kokhanok	78	4	4	4.0
Kwethluk	28	4	4	4.0
Napaskiak	11	4	4	4.0
Newhalen	21	4	4	4.0
Nondalton	26	4	4	4.0
Old Harbor	62	4	4	4.0
Ouzinkie	18	4	4	4.0
Pedro Bay	69	4	4	4.0
Port Lions	19	4	4	4.0
Saxman	2	4	4	4.0
Shishmaref	7	4	4	4.0
Solomon	41	4	4	4.0
Tatitlek	20	4	4	4.0
Tenakee Springs	42	4	4	4.0
Angoon	66	3	4	4.0

Source: NREL Reconnaissance (2001)

3.10 Appendix C: Low Sulfur Fuel Requirements

Economics of Diesel Fuel Sulfur Control

EPA estimates of the economics of diesel sulfur control place the average refining cost at around six cents per gallon for small refineries.

DOE estimates of the average refining costs of low sulfur diesel range from 5.3 to 8.5 cents per gallon.

The low sulfur fuel requirement is for on-road vehicles. Nonetheless, this requirement may effectively require all diesel fuel to become low sulfur.

Since the EPA requires refineries to produce low sulfur fuel, the question is whether refineries switch all of their diesel fuel production to low sulfur, or retain two separate production streams for the diesel cut—one for low sulfur (on-road vehicle market) and one for high sulfur (off-road market)—requiring separate processes and separate storage facilities. Then the fuel terminal, distribution systems, regional and local storage systems are faced with the question of whether to develop separate systems for low-sulfur and high-sulfur diesel fuel. The diesel fuel supply chain may attempt to provide separate streams, or it may just migrate over to one stream to avoid parallel systems costs.

The additional costs for building and maintaining two separate diesel supply streams have been estimated in the 15 to 40 cents per gallon range for Alaska. In addition, due to their small size and high construction cost market, the refineries in Alaska expect the cost for diesel sulfur control to be higher than EPA or DOE estimates.

In addition, if the fuel available to rural Alaska utilities is low-sulfur fuel, there may be additional costs associated with adjusting the diesel engines to run on the new lower lubricity, low-sulfur diesel fuel.

In exchange for certain exemptions and delays of the requirement, the State of Alaska DEC is required to file a low-sulfur diesel fuel plan with the EPA in 2002.

So potential scenarios to consider in the rural Alaska market include:

- In-state diesel fuel refineries are *not* required to switch to low sulfur fuel in the next eight years
    - On-road vehicle, low-sulfur diesel fuel will be supplied from out-of-state refineries
    - Off-road diesel engines will continue to be supplied with high-sulfur fuel from in-state refineries
    - Separate fuel systems may be required where there is a significant local market for both low-sulfur and high-sulfur fuel.
- In-state diesel fuel refineries are required to switch to low-sulfur fuel in the next eight years
    - Low-sulfur diesel fuel will be supplied from in-state and out-of-state refineries

In either event, the effective market limit on what in-state refineries can charge the rural Alaska utility market will depend upon the supply and demand.

In the existing market for undifferentiated diesel fuel in Alaska, the price that in-state refineries can charge for diesel fuel appears to be limited by the price available from alternative suppliers—typically the price for diesel fuel available by barge from Washington State refineries.

Looking to the future, the supply for high-sulfur fuel may be limited to a small set of refineries, including those in Alaska, which have received extended exemptions from the requirements to produce low-sulfur fuel. Compared to the situation where the undifferentiated diesel fuel supply could conceivably come from Alaska, Washington State, and Western Canada, this would suggest a constriction in supply with the nearest substitute product, the low diesel fuel, also potentially requiring some modifications in existing diesel engines prior to burning the fuel. Assume demand for off-road diesel fuel continues at roughly the same level. This would suggest that the price level for high sulfur diesel fuel would tend to increase up to the price level for the nearest substitute product—low-sulfur diesel fuel from out of state. While it may not be politically prudent to institute a price increase for high-sulfur diesel fuel in a quiet stable market, crude oil and petroleum product markets are rarely quiet for long. It is certainly possible to imagine the price level for high-sulfur diesel fuel quickly moving upward in a market where the price for crude oil is rapidly increasing (concerns about stability of Middle East). Furthermore, with little competition and limited near term substitutes, the price for high-sulfur diesel fuel can remain slow to respond to downward movement in the price of crude. Thus, it is possible to hypothesize market conditions where the price of high-sulfur diesel fuel moves toward the price of low-sulfur diesel fuel.

Thus, for estimating the long run price of diesel fuel, it may be useful to consider testing the sensitivity of the reconnaissance models to an increase in the price of a barrel of crude on the order of $22.68 compared to the base case of $21.00 (8 percent increase). This is based on the following assumptions:

- ❑ Incremental cost of 6 cents per gallon at the refinery + incremental cost in remaining fuel supply chain of 4 cents per gallon (to make the math easier)
- ❑ Retail Price/Crude Oil Refinery Ratio of 2.5 [$21.00 a barrel = $0.50 cents a gallon; aggregate average retail price of utility diesel fuel in rural Alaska is on the order of $1.25]
- ❑ An increase of 10 cents per gallon from $1.25 to $1.35 is an 8 percent increase.

Increasing the price diesel fuel by 8 percent in the wind reconnaissance model results compared to the medium wind penetration base case results in the following differences.

Table 3-34. Wind Resource Reconnaissance Model Sensitivity Analysis: Eight Percent Diesel Fuel Increase

	Base Case	Eight Percent Diesel Fuel Increase	Difference
Total Benefits	$38,601,294	$49,708,292	$11,106,998
Total Costs	$33,618,254	$41,825,345	$8,207,091
Net Present Value	$4,983,040	$7,882,947	$2,899,907
Benefit/Cost Ratio	1.15	1.19	0.04
Communities with B/C > 1.0	31	37	6

Source: Wind Resource Market Reconnaissance Model Version 1.3, Sensitivity Analysis (2002)

3.11 Appendix D: Texas Deliberative Polling Renewable Energy Results

See **http://www.awea.org/faq/surveys/**

Table 3-35. Central Power & Light, Corpus Christi

First Choice to Meet Need for New Electrical Capacity	Before Deliberation	After Deliberation
Promote Energy Efficiency	11%	46%
Renewables	67%	16%
Fossil Fuel Plant	11%	29%

How much extra are you willing to pay on average for renewable energy (Residential Customers)?	$5.60 per month

Table 3-36. West Texas Utilities, Abilene

First Choice to Meet Need for New Electrical Capacity	Before Deliberation	After Deliberation
Promote Energy Efficiency	7%	31%
Renewables	71%	35%
Fossil Fuel Plant	Unknown %	Unknown %

How much extra are you willing to pay on average for renewable energy (residential customers)?	$7.83 per month

3.12 Appendix E: Potentially Attractive Wind Opportunities in Rural Alaska

Utility/Community	Population	Total kwh Sold (kwh)	Total Fuel Used (gallons)	Average Long Run Price of Fuel ($/gallon)	kwh Sold per Gallon of Fuel Used (kwh/gallon)	Total Avoided Cost ($/kWh)	Wind Power Class	Wind Power Total Benefits (PV $ Life)	Wind System Total Costs (PV $ Life)	Benefit Cost Ratio (B/C)
Potentially Attractive Candidates										
32 Kasaan	48	241,854	33,771	$1.07	7.2	$0.21	4	$311,238	$314,620	0.99
33 Sand Point Electric Company	842	**3,904,527**	**299,525**	$1.33	13.0	$0.13	5	$2,634,315	$2,675,209	0.98
34 Anaktuvuk	314	**2,914,725**	**232,830**	$1.69	12.5	$0.16	3	$2,581,917	$2,630,706	0.98
35 Pilot Point Village Council	92	459,478	46,339	$1.37	9.9	$0.18	5	$309,671	$316,369	0.98
36 Craig	2,809	22,233,042	157,872	$1.91	12.0	$0.17	3	$1,601,484	$1,647,319	0.97
37 Port Heiden, City of **(29)**	116	784,260	68,676	$1.42	11.4	$0.16	5	$557,638	$580,645	0.96
38 Quinhagak	595	1,198,824	104,322	$1.30	11.5	$0.14	5	$733,077	$792,739	0.92
39 Bethel Utilities Corp, Inc.	5,471	**38,620,953**	**2,958,097**	$1.52	13.1	$0.13	4	$27,691,114	$30,257,244	0.92
40 Ungusraq Power Company (Newtok)	284	338,975	34,955	$1.31	12.8	$0.12	7	$294,578	$322,478	0.91
41 Nelson Lagoon Electric Cooperative, Inc.	87	382,038	36,752	$1.08	10.4	$0.14	6	$287,696	$318,349	0.90
42 Goodnews Bay	256	594,360	54,663	$1.43	10.9	$0.16	5	$284,779	$316,002	0.90
43 Tenakee Springs	93	392,747	36,225	$1.55	10.8	$0.18	4	$275,948	$314,056	0.88
44 Shishmaref	556	1,444,942	122,974	$1.35	11.7	$0.14	4	$1,082,609	$1,234,753	0.88
45 St. Mary's	442	**2,139,904**	**221,363**	$1.18	9.7	$0.15	3	$1,598,195	$1,848,304	0.86
46 Kotzebue Electric Association	2,932	**20,057,702**	**1,470,718**	$1.07	13.6	$0.10	6	$10,498,880	$12,142,765	0.86
47 Old Harbor	276	688,452	61,452	$1.63	11.2	$0.16	4	$489,485	$576,007	0.85
48 Kake	745	**3,000,764**	**242,546**	$1.08	12.4	$0.11	5	$1,758,797	$2,080,121	0.85
Subtotal - Potentially Attractive Candidates	15,958	99,397,547	6,183,080					52,991,423	58,367,686	

3.13 Appendix F: Simplified Break-Even Analysis

Break-Even Analysis

FARM

How much wind (mph at 33 feet) do I need to break-even?

1.15 Avoided Cost

	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.0	$0.13	$0.14	$0.15	$0.17	$0.18	$0.19	$0.20	$0.22	$0.23	$0.24	$0.26
9.5	$0.12	$0.13	$0.15	$0.16	$0.17	$0.18	$0.19	$0.21	$0.22	$0.23	$0.24
10.0	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.20	$0.21	$0.22	$0.23
10.5	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16	$0.18	$0.19	$0.20	$0.21	$0.22
11.0	$0.10	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21
11.5	$0.10	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19	$0.20
12.0	$0.10	$0.11	$0.12	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19
12.5	$0.09	$0.10	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.17	$0.18
13.0	$0.09	$0.10	$0.11	$0.12	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18
13.5	$0.09	$0.09	$0.10	$0.11	$0.12	$0.13	$0.14	$0.14	$0.15	$0.16	$0.17
14.0	$0.08	$0.09	$0.10	$0.11	$0.12	$0.12	$0.13	$0.14	$0.15	$0.16	$0.16

Capacity Factor

	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.0	28.0%	25.0%	22.6%	20.6%	18.9%	17.5%	16.3%	15.2%	14.3%	13.5%	12.7%
9.5	29.9%	26.7%	24.1%	21.9%	20.1%	18.6%	17.3%	16.2%	15.2%	14.3%	13.5%
10.0	31.9%	28.4%	25.6%	23.3%	21.4%	19.7%	18.3%	17.1%	16.1%	15.1%	14.3%
10.5	33.9%	30.1%	27.1%	24.7%	22.6%	20.9%	19.4%	18.1%	17.0%	16.0%	15.1%
11.0	35.9%	31.9%	28.7%	26.0%	23.9%	22.0%	20.4%	19.1%	17.9%	16.8%	15.9%
11.5	38.0%	33.7%	30.3%	27.5%	25.1%	23.2%	21.5%	20.1%	18.8%	17.7%	16.7%
12.0	40.1%	35.5%	31.9%	28.9%	26.5%	24.4%	22.6%	21.1%	19.7%	18.6%	17.5%
12.5	42.3%	37.4%	33.5%	30.4%	27.8%	25.6%	23.7%	22.1%	20.7%	19.4%	18.3%
13.0	44.5%	39.3%	35.2%	31.9%	29.1%	26.8%	24.8%	23.1%	21.6%	20.3%	19.2%
13.5	46.8%	41.3%	36.9%	33.4%	30.5%	28.0%	26.0%	24.2%	22.6%	21.2%	20.0%
14.0	49.1%	43.3%	38.7%	34.9%	31.9%	29.3%	27.1%	25.2%	23.6%	22.1%	20.9%

6.7397

2.7699 Wind Req'd

(mph)	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.0	14.7	13.5	12.6	11.9	11.4	10.9	10.6	10.3	10.0	9.8	9.6
9.5	15.4	14.1	13.1	12.4	11.8	11.3	10.9	10.5	10.3	10.0	9.8
10.0	16.3	14.8	13.7	12.8	12.2	11.6	11.2	10.8	10.5	10.2	10.0
10.5	17.2	15.5	14.3	13.3	12.6	12.0	11.5	11.1	10.8	10.5	10.2
11.0	18.2	16.3	14.9	13.9	13.1	12.4	11.9	11.4	11.1	10.7	10.5
11.5	19.3	17.1	15.6	14.4	13.5	12.8	12.2	11.8	11.3	11.0	10.7
12.0	20.5	18.0	16.3	15.0	14.0	13.2	12.6	12.1	11.6	11.3	10.9
12.5	21.7	19.0	17.1	15.6	14.5	13.7	13.0	12.4	12.0	11.5	11.2
13.0	23.1	20.0	17.9	16.3	15.1	14.2	13.4	12.8	12.3	11.8	11.5
13.5	24.6	21.1	18.7	17.0	15.7	14.7	13.8	13.2	12.6	12.1	11.7
14.0	26.3	22.4	19.7	17.7	16.3	15.2	14.3	13.6	13.0	12.4	12.0

205963 kWhs Req'd

392567 (mph)	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.5	1,924,712	1,718,663	1,552,558	1,415,808	1,301,264	1,203,922	1,120,178	1,047,369	983,484	926,977	876,641
10.0	2,054,405	1,832,207	1,653,476	1,506,595	1,383,747	1,279,479	1,189,873	1,112,038	1,043,799	983,484	929,788
10.5	2,187,082	1,948,075	1,756,257	1,598,908	1,467,502	1,356,113	1,260,490	1,177,507	1,104,813	1,040,607	983,484
11.0	2,322,845	2,066,342	1,860,953	1,692,784	1,552,558	1,433,846	1,332,048	1,243,790	1,166,539	1,098,358	1,037,736
11.5	2,461,805	2,187,082	1,967,618	1,788,265	1,638,947	1,512,702	1,404,565	1,310,903	1,228,989	1,156,745	1,092,554
12.0	2,604,075	2,310,373	2,076,308	1,885,391	1,726,698	1,592,705	1,478,062	1,378,860	1,292,176	1,215,781	1,147,946
12.5	2,749,776	2,436,297	2,187,082	1,984,206	1,815,845	1,673,882	1,552,558	1,447,679	1,356,113	1,275,476	1,203,922
13.0	2,899,033	2,564,939	2,299,999	2,084,754	1,906,422	1,756,257	1,628,074	1,517,376	1,420,813	1,335,840	1,260,490
13.5	3,051,977	2,696,389	2,415,123	2,187,082	1,998,463	1,839,858	1,704,631	1,587,967	1,486,290	1,396,886	1,317,660
14.0	3,208,747	2,830,740	2,532,519	2,291,235	2,092,004	1,924,712	1,782,249	1,659,470	1,552,558	1,458,625	1,375,442
14.5	3,369,489	2,968,087	2,652,255	2,397,265	2,187,082	2,010,848	1,860,953	1,731,903	1,619,633	1,521,069	1,433,846

Break-Even Analysis

GARDEN

How much wind (mph at 33 feet) do I need to break-even?

1.15 Avoided Cost

	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.0	$0.13	$0.14	$0.15	$0.17	$0.18	$0.19	$0.20	$0.22	$0.23	$0.24	$0.26
9.5	$0.12	$0.13	$0.15	$0.16	$0.17	$0.18	$0.19	$0.21	$0.22	$0.23	$0.24
10.0	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.20	$0.21	$0.22	$0.23
10.5	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16	$0.18	$0.19	$0.20	$0.21	$0.22
11.0	$0.10	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21
11.5	$0.10	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19	$0.20
12.0	$0.10	$0.11	$0.12	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19
12.5	$0.09	$0.10	$0.11	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.17	$0.18
13.0	$0.09	$0.10	$0.11	$0.12	$0.12	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18
13.5	$0.09	$0.09	$0.10	$0.11	$0.12	$0.13	$0.14	$0.14	$0.15	$0.16	$0.17
14.0	$0.08	$0.09	$0.10	$0.11	$0.12	$0.12	$0.13	$0.14	$0.15	$0.16	$0.16

Capacity Factor

	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.0	35.1%	31.3%	28.3%	25.8%	23.7%	21.9%	20.4%	19.0%	17.9%	16.8%	15.9%
9.5	37.4%	33.4%	30.1%	27.4%	25.2%	23.3%	21.6%	20.2%	19.0%	17.9%	16.9%
10.0	39.8%	35.5%	32.0%	29.1%	26.7%	24.7%	22.9%	21.4%	20.1%	18.9%	17.9%
10.5	42.3%	37.6%	33.9%	30.8%	28.3%	26.1%	24.2%	22.6%	21.2%	20.0%	18.9%
11.0	44.9%	39.8%	35.8%	32.6%	29.8%	27.5%	25.6%	23.8%	22.3%	21.0%	19.9%
11.5	47.5%	42.1%	37.8%	34.3%	31.4%	29.0%	26.9%	25.1%	23.5%	22.1%	20.9%
12.0	50.1%	44.4%	39.8%	36.1%	33.1%	30.5%	28.3%	26.3%	24.7%	23.2%	21.9%
12.5	52.8%	46.7%	41.9%	38.0%	34.7%	32.0%	29.6%	27.6%	25.9%	24.3%	22.9%
13.0	55.6%	49.1%	44.0%	39.8%	36.4%	33.5%	31.0%	28.9%	27.0%	25.4%	24.0%
13.5	58.5%	51.6%	46.2%	41.7%	38.1%	35.1%	32.5%	30.2%	28.3%	26.5%	25.0%
14.0	61.4%	54.1%	48.3%	43.7%	39.8%	36.6%	33.9%	31.5%	29.5%	27.7%	26.1%

6.7397

2.7699 Wind Req'd

(mph)	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.0	17.8	16.0	14.7	13.8	13.0	12.4	11.8	11.4	11.1	10.7	10.5
9.5	19.0	17.0	15.5	14.4	13.5	12.8	12.3	11.8	11.4	11.1	10.8
10.0	20.3	18.0	16.3	15.1	14.1	13.3	12.7	12.2	11.8	11.4	11.1
10.5	21.8	19.1	17.2	15.8	14.7	13.9	13.2	12.6	12.1	11.7	11.4
11.0	23.3	20.3	18.2	16.6	15.4	14.4	13.7	13.0	12.5	12.1	11.7
11.5	25.1	21.6	19.2	17.4	16.1	15.0	14.2	13.5	12.9	12.4	12.0
12.0	27.0	23.1	20.3	18.3	16.8	15.7	14.7	14.0	13.3	12.8	12.4
12.5	29.1	24.6	21.5	19.3	17.6	16.3	15.3	14.5	13.8	13.2	12.7
13.0	31.5	26.3	22.8	20.3	18.5	17.0	15.9	15.0	14.3	13.6	13.1
13.5	34.1	28.1	24.2	21.4	19.4	17.8	16.6	15.6	14.7	14.1	13.5
14.0	37.0	30.2	25.7	22.6	20.3	18.6	17.2	16.1	15.3	14.5	13.9

205963 kWhs Req'd

392567 (mph)

	Fuel Price										
Fuel Efficiency	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
9.5	601,162	536,772	484,864	442,130	406,335	375,915	349,745	326,993	307,029	289,370	273,640
10.0	641,691	572,254	516,401	470,501	432,111	399,527	371,525	347,202	325,877	307,029	290,249
10.5	683,153	608,463	548,520	499,348	458,284	423,475	393,593	367,661	344,944	324,880	307,029
11.0	725,579	645,422	581,238	528,685	484,864	447,767	415,955	388,374	364,233	342,927	323,982
11.5	769,004	683,153	614,570	558,523	511,861	472,409	438,617	409,347	383,749	361,173	341,113
12.0	813,463	721,681	648,536	588,875	539,283	497,410	461,584	430,584	403,495	379,621	358,423
12.5	858,995	761,033	683,153	619,754	567,142	522,778	484,864	452,090	423,475	398,276	375,915
13.0	905,638	801,233	718,439	651,176	595,447	548,520	508,463	473,870	443,694	417,140	393,593
13.5	953,433	842,311	754,416	683,153	624,210	574,645	532,387	495,929	464,155	436,217	411,459
14.0	1,002,423	884,296	791,102	715,701	653,441	601,162	556,643	518,274	484,864	455,510	429,515
14.5	1,052,655	927,217	828,520	748,835	683,153	628,080	581,238	540,910	505,825	475,024	447,767