Wind Integration Assessment
Phase 1 Report

Prepared for:

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DRAFT

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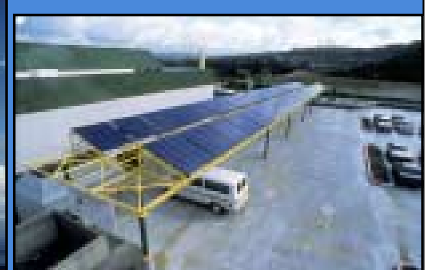

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Executive Summary

Northern Power Systems (Northern) is pleased to provide The City of Unalaska (Unalaska) with this Wind Integration Assessment regarding the proposed wind project in the City of Unalaska and Dutch Harbor.

This report completes Phase 1, where Northern along with the City and with support from Ounalashka Corporation (OC) carried out a site investigation in order to provide a “go/no-go” determination of the basic feasibility of pursuing a wind project. Northern has investigated the areas involved in integrating wind energy into the diesel-powered grid of Unalaska. The outcome is an overview of the feasibility of locating wind generation in Unalaska.

Based on our review of available data the proposed integration of wind power in Unalaska meets or exceeds industry standards.

In order to properly assess the feasibility of a wind–diesel project several key technological and economic parameters need to be evaluated. These include the following:

Wind resource
Site conditions and constraints
Impact on powerhouse operations
Economics
Permitting

The available data to determine the feasibility is limited; no specific wind resource data has been collected, the electric load is growing, available generation equipment and infrastructure is in flux as the City is in the midst of expanding the diesel plant, and considering the use of processor generation capacity. The other significant factor is the availability and suitability of sites for wind turbines. These are the prime factors effecting the installation of a wind hybrid system. This report considers these factors and provides an assessment of whether wind power makes sense for Unalaska.

Prime wind farm sites identified are: Pyramid Valley, Strawberry Hill, and South Road. These areas possess a wind resource with an estimated annual average wind speed of at least 7 m/s (15 mph), the basic infrastructure, access, land use, integration, and permitting potential, along with qualities the City wishes to meet. These three sites were chosen for further investigation from seven sites investigated.

Investigation shows that the project can be installed using standard construction and erection methods and although installations at the potential sites are more complex and expensive than typical wind farms sites, they can be achieved using local practices. Interconnection with the local distribution/transmission may be accomplished, and is a cost issue rather than physical barrier. Integration with the current powerhouse, along with the planned powerhouse changes may also be accomplished with excellent benefit while ensuring power quality and reliability. Integration of wind power into the existing diesel grid will take detailed design, but the methods are now mature, and proven in Alaskan applications.

The project would be a strong fit with Unalaska's environmental, economic, and risk reduction goals and could be designed to meet the payback/life cycle cost threshold. Depending on the ownership structure the project may also be able to take advantage of green energy incentives and tax benefits, which may provide additional contribution to the project economics.

The main challenges to wind power in Unalaska are twofold:

- Permitting process: Historic site review (approval by SHIPO) and the Fish & Wildlife Dept.'s determination of avian concerns regarding the eider and eagles.
- High wind gusts and cold weather issues (storm winds, turbulence, complex terrain, icing events, and turbine wear/operating costs from these events). These operational concerns present added challenges for wind project performance, however, there are turbines available that would perform in these conditions.

Providing better definition to these issues may be accomplished by the installation of a meteorology (Met) tower(s) on the potential site(s). These installations will allow "a wind energy-based" quantification of the turbulence, and potential for storm damage and wear. A met tower can also provide further information on avian interaction (with the use of monitoring equipment), and enable visualization through the use of actual wind turbine size "flags" to be flown for demonstration purposes.

As the project meets or exceeds all of the technical and economic thresholds at this preliminary feasibility stage, Northern recommends that Unalaska move forward with Phase II of the feasibility analysis.

Phase II would include:

- Institute a formal site resource investigation
- Delve into the required technical, cost issues
- Map out permit and environmental site issues, and process
- Provide the information needed for a variety of contract/operational solutions to be explored, especially integration/control needs for the new diesel plant

Background

The City of Unalaska is following through with a DOE-funded process to ascertain the viability of integrating wind energy into the existing diesel engine powered grid serving Dutch Harbor and the City of Unalaska. The area is the largest port in Western Alaska and handles significant freight, both for general delivery to the smaller communities, and for support/transshipment to the fisheries and seafood processing facilities located in Unalaska.

Electric supply is a crucial part of Unalaska's infrastructure. With an electrical demand of over 8MW, electricity generation is a large issue with the need to consider fuel price volatility, air emissions, and fuel storage.

The City is considering the ability of wind power to reduce costs, improve air emissions, reduce fuel storage needs, and provide other benefits to the Community. Although these benefits are clear they must be weighed along with the high capital cost of wind power, the sensitive wildlife issues presented by a large amount of local bird activity, aesthetic concerns, and potential for storm winds that may limit the viability of commercial wind turbines.

The Unalaska area has a viable wind resource, and several potential wind sites. Various entities in the surrounding area have implemented wind power (TDX Corp. on St. Paul Island) or have explored its use – Sand Point, Cold Bay, St. George Island and of course Unalaska. AVEC, the largest cooperative utility in Alaska has been a leader in wind power integration starting with the Village of Wales, then Selawik, and now Toksook Bay, and Akula Heights (Kasigluk).

A previous wind energy study was made in 1999 by Dames & Moore, which looked at potential sites, available wind speed data, and wind turbine brochures. The study did not present any conclusions, nor provide direct integration data other than name possible wind turbine sites to be explored. These sites were: City Landfill, Haystack Hill, The Spit, the Wastewater treatment site, and Pyramid Valley.

The goal for this Phase I study was a review of all factors effecting the utilization of wind power, focusing on wind resource, and integration with the diesel generation assets, and site specifics. This focus has allowed sites to be specified for the installation of Met tower(s), and to offer further understanding of wind integration, and potential wind capacity as the new diesel plant is being designed and phased in.

Northern Power Systems is a leader in the field of wind-diesel system design, controls, and implementation. Integration with a diesel plant can be a complex endeavor, and this report has addressed the basic constraints, and costs of this effort, to ensure the City is armed with all cost data, and balance of system information associated with a project of this nature. The City has an ideal opportunity as it upgrades its generation facilities, to integrate controls and possible power quality components for the smooth integration of wind power. Wind power can help the City meet its goals of reducing fuel use, narrowing exposure to fuel price volatility, addressing air emissions, limiting future fuel storage needs, keeping more money in the community, and providing more employment.

The study included a three-day site visit, examining potential wind sites, learning about the planned development of the powerhouse and considering the overall generation plan of including the fish processor capacity. Interviews were performed to determine City needs and barriers to development of either distributed wind turbines or a small wind farm. The missing link is wind resource data measured at typical wind turbine hub height.

The conclusions drawn from this Phase I report will allow the City and its residents to discuss the application of wind power, review potential sites for ownership and implementation, all with a better understanding of its benefits and limitations.

Available Data and Assumptions

The intent of this Phase 1 report is to provide adequate information to enable Unalaska to make an informed decision on whether to go forward to the next phase of the feasibility study. Existing data, previous studies, interviews, and similar data from nearby locations have been used to compile this report.

Sources

The report is based on the following information:

- Existing wind resource data, site topography provided by Unalaska, and various State of Alaska and Federal Agencies.
- Site review by Northern staff on December 9 - 11, 2003
- Meeting with Chris Hladick, City Manager, Robin Hall City Planner, Wendy Svarny-Hawthorne (CEO – OC), and various City staff, Powerhouse Manager, and informal discussions with the Mayor, and City Council. Follow-up discussions with City Staff have been held as we gathered data and evaluated site constraints.
- Discussions with other utility operators in the Aleutian's and Alaska
- Discussion with City of Unalaska's powerhouse consultant (Dave Hubbard)
- Conversations with local staff, residents, officials. (refer to "Trip Report" in Appendix E)
- Evaluation of standard engineering and installation costs
- Review of available and appropriate wind turbine technology
- Consideration of the impact of weather and turbulence on wind turbine operation and maintenance

Assumptions

The following assumptions concerning the character of the data available to Northern should be noted:

- The wind resource assessment data gathered from the agencies is not site specific
- The estimates for foundation engineering and construction are based on a standard ballast foundation and assumption that sites would be suitable for this type (Northern did not receive site-specific geotechnical data).
- Electricity transmission/distribution one-line diagrams for the area have been reviewed in general for suitability at this stage, upgrades may be required depending on the site. Further details would be investigated, and described in Phase II.
- Electrical data, demand, generation, are based on a conversation and the report prepared by Dave Hubbard, in Maine from 2002/2003

- The avian review was carried out by ABR Inc., based in Fairbanks, who has done several studies on the Aleutians, please refer to the review in Appendix C for specific assumptions.

This Wind Project Evaluation Report, by itself, is not enough to adequately address a definitive description of installation cost, wind resource data and site constraints. Before Unalaska invests in this project we recommend several additional steps outlined in the Recommendations section of this report. These steps would constitute a normal process of completing project engineering and contracting estimates before committing to wind power as a significant generation asset and before procuring equipment and installation services.

Wind Resource

Wind resource is the most crucial aspect of wind power. As wind energy is a cubic function of wind speed, small increases in wind speed provide significant additional energy.

The wind resource in Unalaska is good, and more energetic than sites that already have implemented wind projects. Northern estimates an annual average of at least 7 m/s (15.4 MPH). Northern believes this number may be conservative, and expect more resource if correct siting is made. Surrounding areas, such as St. Paul Island, have annual averages of 8.5 m/s; Unalaska's resource is more limited by the topography than the available winds blowing through. A resource of 7 m/s can deliver economic wind power. The resource is seasonal (lower in the summer), but predictable due to the weather patterns of this region of the Bering Sea. The Japan Current, and temperature conditions often produce sweeps of weather – lasting for several days. These bring strong winds offering a stable source of energy. The weather events also induce significant storm winds, some over 100 MPH. These conditions are over the typical 60 MPH shut down speed of wind turbines, and can cause accelerated wear and potential damage to wind turbines.

Unalaska, and Dutch Harbor also have complex terrain, sharp hills and narrow valleys - conditions that cause turbulent winds. These winds can have gust factors, and angular components that induce uneven loads on wind turbines. Wind turbine siting is an important task, although a wind turbine site may be ideal regarding visual exposure (i.e. hidden behind a slope) this location may reduce output, and cause extreme wear.

The available data for Wind Resource is summarized in Table 1. The data is has limited value, as it was not collected at a potential wind site, was not collected at the correct height, and some of it was not "collected" at all, rather, they are estimates based on models. For the purposes of this report, we have defined an expected minimum of 7 m/s wind speed. A detailed review of the data is beyond the scope of the Phase 1 effort, and is not worth the effort fro the reasons listed above.

Table 1—Review of available data

SOURCE	AVG WIND SPEED			
	m/s	MPH	Location	Equip
Alaska Electric Power Statistics 1960-1995	8.00	17.84	Unalaska	
Western Region Climatic Center 1996-2002	5.02	11.20	Unalaska Airport	
Dames&Moore Report May 1999	5.20	11.60	PyramidValley	20ft tower
Dames&Moore Report May 1999	5.70	12.80	RockyPoint	30ft tower
Various city web sites	7.62	17.00		
www.city-data.com	7.65	16.83		
CH2MHill; Jul-Aug93; Hog Island & Spit	4.76	10.47	Hog Island	
CH2MHill; Jul-Aug93; Hog Island & Spit	4.43	9.76	Spit	
CH2MHill; Aug-Dec93; Hog Island	4.52	9.95	Hog Island	
CH2MHill; Jan-Feb94; Hog Island	5.54	12.20	Hog Island	

Note: Data sets are not complete, and minimal equipment, site specifications are available

Resource Conclusions:

- The data portrays a wind resource of at least 7 m/s annual average should be available at the various sites. The winter average winds will be higher, and offer a high Capacity Factor.
- High gust values are present, as would be expected in the Aleutians, and must be considered when evaluating wind turbine mechanical and lifetime performance.
- Turbulence will occur. This is of concern as are gusty winds, and should be addressed in the site evaluation, micrositing tasks
- The combination of the average speed and gust values put the site into a wind turbine design class: WTGS Class 2 or 3. The International Electro-technical Commission, an international body governing wind power standards, administers this standard designation. Although this class may not have high-energy value, the extreme gust must be considered and used to factor the design class. This means the wind turbines to be used should be designed, built and certified to withstand the challenges presented by this wind resource classification.
- Further information and analysis of the high wind speeds is required, in order to predict the lost energy when the wind speed is too high (wind turbines shut down).
- On site data collected at wind turbine hub height must be collected. Multiple levels of anemometry will allow many of the unknowns to be quantified.

Site Constraints

Unalaska presents challenges in the siting of wind turbines, although not necessarily anymore than other locations. Whether the turbines are sited in a concentrated wind farm setting, or distributed around the City and harbor, a variety of issues will have to be addressed. These issues are primarily related to environmental impact, visual impact, noise generation, and safety.

Issues related more specifically to Unalaska would be particular avian concerns, logistics, handling and site access. Wind turbines require heavy equipment, roads, crane pads, access to compatible distribution lines, and land that is available and economical.

A summary of infrastructure and permitting issues to be addressed follows.

Infrastructure

- Preliminary investigation shows reasonable soil conditions for foundations, collection and distribution system installation.
- Existing electrical distribution is available, and compatible with the wind power configurations considered.
- Distribution, collection systems can be installed per the standard City utility practice, using both above ground and buried conductors.
- Typical construction techniques (excavation/concrete/material handling/contracting) may be used for the wind project, and would work well in conjunction with other planned construction projects, especially for mixing large amounts of concrete.

  Cranes will need to be brought on island to meet the specification required. The existing cranes available are suitable as assist cranes only. The large MW size wind turbines considered require a 200-ton crane minimum, with long booms. (i.e. Manitowoc 2250 Series 3) The availability/practicality of crane size will drive the choice of turbine.
- The existing single-track roads to most sites can be upgraded to provide the necessary access for both construction and ongoing O & M without significant modification, added drainage, or impact to the natural area. Roads can be narrowed after construction.
- Security fencing will not be required for a project as equipment is located internal to the tubular towers
- The existing operations group of the City Utility/and its Lines Dept. is well suited to take on the normal operations and maintenance of the wind turbines. Factory technicians can support local personnel via remote monitoring packages, and would be called upon for recommended “majors”.

Permitting

Northern did not conduct a formal permit review. A review of requirements was carried out with the City, and via phone with several agencies. The following permitting information was gathered:

- The Forest Service has been operating under the guidelines set forth by the Bureau of Land Management related to wind and energy project construction. Their exists a wind power project review process through the BLM, The regional Forest Service office will be responsible to determine the review for Unalaska.
- Initial public scoping, and informational meetings for wind have been undertaken and the primary concerns raised related to:
  - visual impact
  - noise
  - avian issues
- A Fish and Wildlife scientist will need to complete a bird survey in Spring 2005
  - Review is required for the Met tower, for consideration of possible equipment to be added to protect against birds flying into the guy wires.
  - Avian activity may also be monitored during the Met study
  - Recent work from other Fish & Wildlife offices outside of Alaska can be considered during the Unalaska study, along with private work from ABR.

- An Environmental Assessment could be complete by Summer 2005
  - The Forest Service may be able to provide funding for the Environmental Assessment, which according to the Forest Service may cost $5,000 - $8,000
- SHIPO review for WWII artifacts will need to be considered, as Unalaska is required to contact SHIPO for review. No formal response was received from SIPO related to wind power, although once sites are determined, review may get underway

Permitting issues will focus on Avian concerns. The available data to determine the impact wind turbines may have on avian populations has increased significantly in recent years. The wind power industry has been proactive in supporting research, and wildlife biologists have spent more time in the field studying existing installations. Alaska has several wind projects moving ahead, therefore local understanding has improved. Certain Eider species are of concern, and will be the focus, along with the Eagle population. The Avian Review in Appendix C offers a detailed discussion on current understanding, Unalaska avian populations, and wind power interaction.

Impact on Utility Operations

Experience has shown that Wind power plants can be maintained and operated by a rural electric utility. The main concerns may be the required skills for operating wind turbines, impacts to grid stability, overall power quality and safety.

Wind turbines require similar skills to a diesel plant for operations and maintenance, and training can create a ready and able workforce for routine work. Manufacturers provide full warranties, and service contracts, ensuring sustainable operation of the equipment.

Power Quality is one of the typical issues mentioned when considering the integration of wind power into isolated grids reliant on diesel generators. Much work has been done over the past twenty years on system configuration, controls, and balance of systems. Wind turbines have also become more sophisticated, and able to be more forgiving as they partner with diesel generators in supplying quality power.

As envisioned, a medium to high penetration wind power configuration in Unalaska will provide the most economic benefit, as it will curtail diesel engine run time. As long as correct balance of system components are included (capacitor banks, secondary load, potentially a synchronous condenser or electronic equivalent). the grid system will remain balanced, without flicker, voltage concerns, nor undo reactive power consumption. A Wind –Diesel System technology Primer has been included in Appendix G

Safety concerns may stem from ice being thrown from the blades if the machine starts up after an icing event while a person is within a specific ice throw area. Current studies for application of wind power in much more dense areas (such as Europe) have shown this to be of little concern after normal precautions.

Isolated grid communities similar to Unalaska have undertaken wind –diesel and been successful. The country of Chile, has a ~2MW system, Canary Islands, several islands in Greece, and Northern Europe. A mature group of manufacturers in the USA, Australia, and Europe offer know-how, design, and equipment, providing the utility with alternatives to build and support a system.

On the whole, Utility operations will receive lower fuel costs, reduced pressure from emissions regulations, longer life of the diesel plant and if designed correctly – improved power quality.

Project Economics

The following Project Economics section provides an overview of the economic picture of integrating wind power; its installed costs, electrical output, life cycle costs, and potential alternative financial benefits. Wind power looks favorable.

Wind Turbines

Northern has selected three different wind turbine options, providing a look at small (250 kW), medium (660 kW), and large (1500 kW) wind turbine offerings. The expected annual output (MWH) is listed in Table 2. based on the 7 m/s annual average. Raw output is shown based on a Rayleigh Distribution for the predicted annual average wind speed. Colder average temperatures have a positive impact on air density. This was considered by using a power curve adjusted for air density, therefore increasing output in Unalaska.

Net Production

As with all wind projects, net annual production will be reduced by a variety of factors, including: icing, turbulence, electrical losses, and wake/array losses. The number of turbines, and the spacing of those machines will drive array losses. All turbines will experience downtime due to regular maintenance or for repairs – we have applied the industry standard for Availability (i.e. 2% of the time they will not able to generate power) across all of the turbines.

Raw output reduction summary:

1. Availability of 98%
2. Electrical losses of 6% (collection wiring, transformers, distribution)
3. Shut Down of 7% (local weather related: icing and high winds)

Giving total losses of 15%

Table 2—Energy Production Estimates (MWH)

Per Unit Production	GE 1.5	Vestas V47	Fuhrlander 250
Raw Production (MWH)	4,273	1,911	602
Net Production Less 15% Losses	**3,632**	**1,624**	**512**

Wind Power Configurations

Three configurations using three different turbines of 6MW, 6.6MW and 2.5MW have been modeled for potential installation. These are large quantities, but offer a look at the potential for a major part of the utilities demand The 6MW, 6.6MW configuration represents a wind "penetration" of roughly 50% of the current demand on an overall energy basis. This is considered medium to high penetration, as the nameplate capacity of the wind turbines are over the City demand at certain periods. This configuration takes advantage of economies of scale, makes wind power a significant contributor, and provides the ability to shut down engines, offering an opportunity for wind power to provide real benefit to the power plant economics. The 2.5MW configuration was included as an example of smaller wind turbines. The smaller size is not economic with the current price of small wind turbines, and without real savings on construction costs. The City should continue to consider configurations over 4MW to enable significant diesel plant impact, and realize the benefits of wind power.

Performance and Cost

The following table presents an analysis of three potential project scenarios using wind turbines appropriate for Unalaska. It is intended as a comparative tool in evaluating potential configurations relative to project cost. It does not include other turbine and project considerations such as size, visual impact, cold weather reliability, serviceability, and warranty or control systems performance.

For the purposes of this first stage feasibility evaluation we have provided a simple payback analysis. It does not take into account the time value of money, or specific tax benefits applicable to Unalaska.

Table 3—Project Economic Comparison

	GE1.5	Vestas V47	Fuhrlander
Unit Size (kW)	1500	660	250
# of Turbines	4	10	10
Installed Capacity (kW)	6000	6600	2500
Wind Systems complete fob, Unalaska	$7,495,200	$6,674,400	$3,745,000
Permit/Legal/PM/Engineering	$670,106	$636,600	$426,000
Installation & Commissioning *(includes Foundation Construction and Electrical Collection System)*	$904,976	$1,155,106	$739,041
Total Project Costs	$12,693,939	$12,576,128	$7,366,849
Installed Cost ($/kW)	$2,116	$1,905	$2,946
Total Project Cost after Federal Tax Credit and MACRS Depreciation Estimate*	$7,425,954	$7,357,035	$4,309,607
Annual Maintenance	$170,926	$162,456	$103,942
Annual Energy Output (MWH)	14,528	16,246	6,929
Lifetime COE $/kW (20 yr lifetime)	$0.077	$0.070	$0.124
Avoided cost of power (diesel offset)	$0.12	$0.12	$0.12
Production Tax Credit (10 yrs)	$2,353,657	$2,631,789	$1,122,574
Green Tag Value (10 yrs)	$1,307,587	$1,462,105	$623,652
Simple Payback (yrs)	5.5	4.8	10.6

Assumptions

The following assumptions were used in preparing the simple economic analysis in Table 3 above. (A more complete list of assumptions that were made in preparing this analysis is provided in Appendix D):

- Installation cost estimates were made with remote Alaskan construction in mind; bad weather allowances, unexpected soil conditions, equipment downtime.
- The average avoided cost of power over the 20-year lifetime is based on a portion of avoided fuel cost only as not all wind power will replace diesel. Conservative fuel cost: $ 0.12/kWh (even though the utility currently considers 0.14/kWh the fuel cost)
- The Federal Tax Credit and MACRS Depreciation Estimate includes a 10% Federal Tax Credit and an additional 35% savings due to tax benefits associated with depreciation.
- The Federal Production Tax Credit of $0.018 per kWh generated as in current law
- Regarding Green Tags:
    - o The value of the Green Tags (the green power attributes associated with wind power) is $0.01 per kWh

- A discount factor and the time value of money has not been incorporated

Based on the above, the following conclusions can be drawn:

- The installed costs are in the range of large wind diesel systems
- The large configurations meet the payback requirements outlined by Unalaska,
- The lifetime cost of energy (COE) is competitive with utility supplied power.

The GE machines may offer the attraction of only four machines, but are more expensive in this particular review. In addition, the GE machine may be too large, the manufacturer may not warrant the turbine for this application/site conditions and/or a large crane may not be available or cost effective. For your information, the wind turbine on St. Paul Island is a Vestas V27 (225 kW).

Diesel Generation Offset

Low cost wind power can offset significant diesel generated megawatt hours (MWHs). The preliminary run for 10 Vestas V47's predict 11,372 MWH (70% of 16,246 –see explanation below). These wind generated MWHs save considerable fuel consumption. Wind power can be referred to as a negative load, thereby reducing demand on the diesels, allowing the diesel controls to throttle back and save fuel. There are limitations on fuel savings in this regard, as engines prefer to run well loaded, fuel consumption curves are not conducive to low load operations, and the engines will still wear, therefore O & M costs are reduced only marginally. New diesel engines are better able to respond to this situation, but the real goal is to shut engines off in order to save fuel and reduce O & M, emissions and fuel storage. Multiple diesel plants can be configured and controlled to allow engines of varying sizes to be run when needed. This allows concise load matching, and is similar to what a normal diesel plant does. While wind-diesel controls and systems are now prevalent and mature, there are still limits on how much savings can be attained by the integration of wind into a diesel grid.

More details of wind-diesel system technology, types, power quality issues, and modes of operation are discussed in Appendix G.

The for diesel plant impacts, the performance figures in Table 3, consider the following limitations:

1. Only 70% of the wind power can be used in the grid. Wind power may not be needed at the time it is generated, or if used at certain times, might result in unstable and/or unsuitable diesel plant operation. The remaining 30% can be used for a Secondary Load, i.e. productive uses such as heating buildings, through the use of a hydronic system with electric boilers.

2. At certain times a wind turbine may be curtailed (shut down) to maintain power quality, and diesel loading in high winds, low load conditions. This would occur when the Secondary load cannot absorb power at that moment.

While these requirements hurt the economics of wind-diesel, through careful system sizing and design major benefit can still be found, as wind has a much lower life cycle cost. The preliminary numbers show wind power costs of 6 – 7 cents/kWh, well under the current 14-cent/kWh diesel fuel cost of generation. Additional savings in reduced O & M, and fuel storage requirements (industry figure of +$7/gallon for new fuel storage facilities) show very promising results. The performance numbers listed, did not value the 30% of wind energy going to the Secondary load. Depending on its use the value will vary, but the utility Hydro – Quebec estimated that this energy had a value of 5 cents/kWh ten years ago.

The next phase in the feasibility study can model specific scenarios with real power plant configurations to determine the final value of wind –diesel generation for Unalaska.

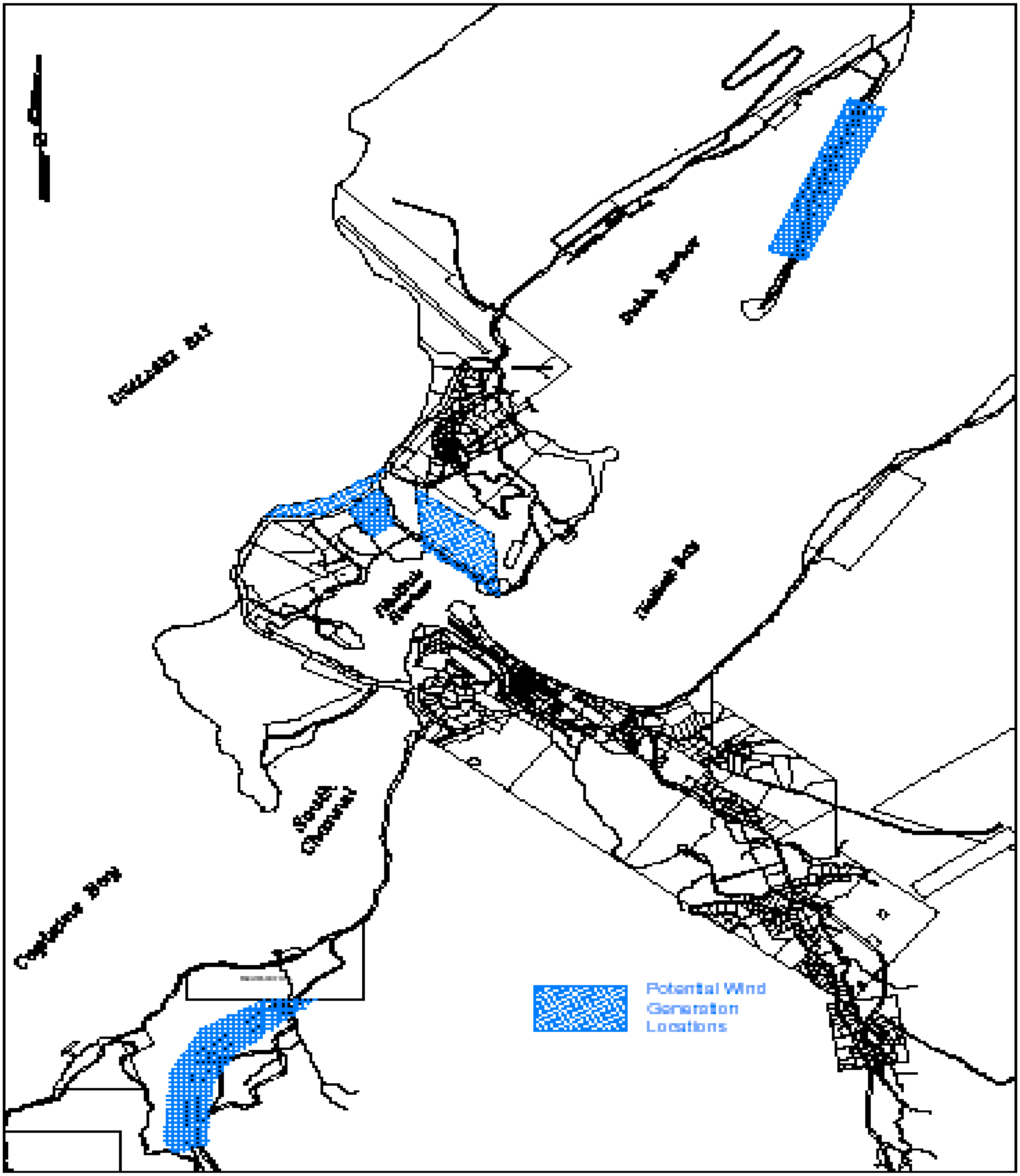
Recommendations

Based on this first stage feasibility evaluation of the existing wind resource, site logistics and available turbine equipment, a wind project in Unalaska is technically and economically viable and is worth pursuing. The City should continue on a path to gather additional site data necessary for project construction internally review the financial costs and benefits of the project and obtain permits for the met towers.

As part of this process in order to more fully develop the project before committing financial resources, Northern recommends a number of specific steps be taken.

- Initiate collection of wind resource data including addition of a temperature sensor at the Pyramid Valley Site.
- Engage the Fish & Wildlife Service and SHIPO in discussions and permitting activities for the Pyramid Site and one of the other potential sites determined during the Cities review of Phase 1.
- Move forward with Phase II of the feasibility: Preliminary Project Design

Phase II will build on the gathered data of Phase I, and
Institute a formal site resource investigation
Delve into the required technical, cost issues
Map out permit and environmental site issues, and process
Provide the information needed for a variety of contract/operational solutions to be explored
These tasks will provide documented project information that the City may use to plan, fund, contract, and implement the project. This information will be required in order to have contractors and/or developers formally respond to the City.


Potential Wind
Generation
Locations

Appendix B – Trip Report

Unalaska - Dutch Harbor Alaska Trip Report

Dec 8-11,2003

Sat Dec 8 – Sun Dec 9:
Burlington,VT to Dutch Harbor,AK

Sun Dec 9
Arrive at Dutch Harbor airport. Met by City of Unalaska Manager, Chris Hladick.
Chris gave us a tour of Amaknak and Unalaska Islands including the Spit, UniSea, APL, LSA (Little South America), Western Seafoods, Bunker Hill, Pyramid Valley, small boat harbor, Snow Bowl. Lunched @ local church fundraiser with Chris. Later Lawrence and I returned to Pyramid Valley, small boat harbor, and Snow bowl.

Mon Dec 10
9am meeting with City Planner, Robin Hall, discussed potential wind turbine sites. These included

- Pyramid Valley,
- The Spit,
- Strawberry Hill,
- Front of Eagle Store/Grand Aleutian,
- west of UniSea (between UniSea & Bay).

It was determined that a letter from city manager Chris Hladick be sent to State Historic Preservation Office (SHPO) and the Fish & Wildlife Service describing our desires to look at these particular sites and determine if they had any preliminary objections.

Most sites were property of Ounalashka Corporation (OC). We scheduled an afternoon meeting with OC. Met with Wendy Svarny-Hawthorne (CEO), along with Dave, and Denise of Ounalashka Corporation to discuss potential sites. They're initial impressions appeared to be receptive to utilizing the sites for wind energy. Wendy indicated she would present the ideas to the OC.

Lunched with Aimee Kniaziowski(?-AsstCityMgr), ChrisHladick, Glen Fitch (PowerPlant Supv), Dave Kemp (Public Works) and Mayor Pam Fitch at the Grand Aleutian at the offer of Chris.

Received a tour of the city power plant by Glen Fitch. His phone numbers 581-1831 office and 391 3552 cell.

7pm at the invitation of Chris Hladick, Lawrence presented a 20min presentation on wind energy to the monthly city council meeting. Attendees included Mayor Pam Fitch, Bill Bradshaw (ex-PublicWorks) and Don Graves (UniSea). Bill Bradshaw indicated that the town had wind data available from previous studies.

Tue Dec 11:
Met in the morning with Chris Hladick. Took Lawrence to airport. Met with US Coast Guard regarding the collection of wind data. Office has been located on Unalaska for 5 years. Coast Guard office is located on Amaknak Island approx half mile from airport heading towards Unalaska Island. I was told the measuring devices were not working and they have no historical wind data.

Drove to end of paved spit (land area of spit continues for approx another half mile of which a dirt road exists for a portion) and photographed anemometer.

Returned to City Hall. Chris and I called Bill Bradshaw (Ex-Public Works) to ask about his knowledge of previous wind data. Bill referred us to Public Works. We called Dave Kemp. Dave brought several documents for me to review and copy.

Checked with Robin Hall concerning any preexisting soils data. She indicated to check with Public Works. I spoke again to Dave Kemp about the availability of any soils data in his possession. He brought over additional documents.

All documents from Public Works and the City that were copied and in our possession have been listed in the spreadsheet UnalaskaDocuments.xls

Met with APL (large container crane) Mary (office admin) & Perry (crane operator/supv?) concerning any wind measuring devices and data that they may collect. Perry took me to the control room on the crane. Wind measurements are kept in 15 min intervals. No electronic recording is done. Once a week hand recordings are done. Perry indicated that he was willing to do more recordings for us and /or allow us to install monitoring equipment. He thought there was an additional anemometer in their shop that he was offering us the use of.

Was provided the name of Reggie X(?) at the airport as a contact for owner of weather data. Photographed anemometer at the end of the airport runway. The airport lost their AWS weather station during the high wind (+160mph) event the previous week. There is an additional anemometer located at midfield of the airport. Reggie regularly records wind and weather data by hand daily and sends to the NWS in Anchorage 907-271-5122.

Spoke to Dale Rodda @ NWS Anchorage. He indicated that the NWS in Anchorage does a QC check of the data sent to them by Reggie. It is then sent to National Climatic Data Center, 828-271-4800, www.ncdc.noaa.gov and to Western Region Climatic Center, 775-674-7010, www.wrcc.dri.edu. Spoke to Jim Ashby @ WRCC. He indicated that monthly averages taken from data spanning the years 1996-2002 are available on their web site. They also have available daily data for each of those years for a price of $25/year with a maximum charge of $100 for 4 or more years.

Wed Dec 12:
Lunch w/Chris Hladick & Wendy Hladick @ Grand Aleutian.

Met again with Perry from APL to ask about availability of crane size/capabilities. He indicated drawings could be made available. Perry is working there until Feb on a temporary assignment out of Seattle. He also indicated that the local longshoremen were limited in their abilities at handling anything other than a standard container.

Met again with Reggie at airport to retrieve any data he had concerning FAA limits on obstructions. Reggie referred me to (?) in the airport maintenance shop. That person provided me with several FAA documents relating to construction of objects in proximity to airport.

The site visit was successful in obtaining:

- a number of wind sites to pursue,
- in meeting with decision makers, informing these decision makers and certain entities, such as F & W.
- We have land maps, one line details,
- An understanding of power plant operations, and typical load scenario's
- A large number of photographs, and understanding of the topography, and site conditions
- A knowledge of available infrastructure: including, docks, cranes, heavy equipment, concrete, distribution, contractors, and skilled labor.
- Preliminary wind data is available for the town/harbor

Next Steps:

- Obtain more wind data from NOAA, or Airport, possibly private source
- Confer with Chris Hladick on response from SHOLP and F & W
- Follow up with OC, and openness to siting wind facilities on OC land
- Discuss rates with OC
- Conduct another level of power planning review: such as Air quality issues, processor generation, future load scenario's, other issues related to an effective design for power generation in Unalsaka/Dutch harbor
- Obtain migratory bird report

PRELIMINARY ASSESSMENT OF BIRD ISSUES AT A PROPOSED WINDFARM NEAR DUTCH HARBOR, ALASKA

Robert H. Day and Robert J. Ritchie

ABR, Inc.—Environmental Research & Services, P.O. Box 80410, Fairbanks, AK 99708-0410
4 February 2004

Dutch Harbor–Unalaska is a moderately-sized, busy fishing community in inner Dutch Harbor itself. This is the largest fishing port in the US, in terms of amount and/or value of commercial landings. It also has a substantial amount of fisheries processing. Because of both the very active fishing and processing activities and the protected nature of the bay, it is a magnet for birds throughout the year.

There are three main bird taxa in this area that may interact with any windpower development: waterfowl, Bald Eagles, and gulls (several species). These taxa are important because of their abundance, their legal status and protection, and/or their movements or areas of concentration.

Waterfowl includes a large group of species, all of which are protected under the Migratory Bird Treaty Act (16 USC 703). Three main species are of note: Steller's Eiders, Emperor Geese, and Harlequin Ducks. Steller's Eiders also are protected under the Endangered Species Act (16 USC 1531). Only the Alaska breeding population is protected (the Russian birds, which form a majority of the entire wintering population in Alaska, are doing well), but, because the two populations mix in Alaska during the winter, the entire wintering area is of concern. Several hundred Steller's Eiders winter in the bay, foraging near the coastlines and over small shoals (Table 1, map). Emperor Geese have declined in numbers on their breeding grounds and winter along shorelines throughout this region (Table 1). Harlequin Ducks, which are considered a Species of Concern by the U.S. Fish and Wildlife Service, occur here all year but winter in large numbers (Table 1).

Bald Eagles are protected under the Bald and Golden Eagle Protection Act (16 USC 668). They breed throughout the area, although not in particularly large numbers, and occur throughout the area throughout the year (M. Jacobson, USFWS, Juneau, AK, in litt.). In winter, they concentrate in the bay in large numbers (Table 1), probably coming in from other islands. They probably concentrate here because of access to food at the landfill and because of the easy availability of food from fish-processing and fishing activities.

Gulls (a combination of various numbers of primarily Glaucous-winged Gulls, Mew Gulls, and Black-legged Kittiwakes) are protected under the Migratory Bird Treaty Act. They occur in the bay in various numbers throughout the year. Glaucous-winged Gulls and kittiwakes nest in the area, although not in large numbers. They especially concentrate in the bay around outfalls of fish-processing plants and near fishing boats in general, especially in winter (Table 1).

Table 1. Counts of bird species of interest on the annual Christmas Bird Count (one day in late December each year) for Unalaska–Dutch Harbor.

	YEAR		
SPECIES	2000	2001	2002
Emperor Goose	1031	1418	1272
Steller's Eider	703	546	696
Harlequin Duck	1016	629	969
Bald Eagle	622	681	878
Gulls	1026	186	782

We evaluated all five potential site locations with Daniel D. Gibson (University of Alaska Museum, pers. comm.), who has conducted several recent bird surveys in the bay. Site numbers are marked on a map that we have faxed, ranging from 1 for the northeastern site to 5 for the southwestern site.

Site 1: There is a submarine effluent outflow from canneries near this spit, so many birds concentrate in this area. Gibson has counted at least 700 gulls (primarily Mew Gulls + some Glaucous-winged Gulls and Black-legged Kittiwakes) foraging and concentrating in this area when fish-processing is occurring. He has not seen Steller's Eiders in this area.

Site 2: Many ducks, including scaup, goldeneyes, mergansers, and Harlequin Ducks, overwinter nearby in Iliuliuk Harbor; probably only a few Steller's Eiders do so, however. Nearby Strawberry Hill has the only grove of spruce trees in this area, so many passerines and small raptors are attracted to this site.

Site 3: This is a low, flat, and grassy area in town. Because this area is so low, some birds pass through it when they are crossing over Amaknak Island. In addition, this grassy area concentrates some migratory birds such as golden-plovers.

Site 4: There are large numbers of overwintering Emperor Geese, Steller's Eiders, gulls, and shorebirds such as Black Oystercatchers along this coastline. Eagles also forage here commonly.

Site 5: The number of birds seen drops off quickly as one heads inland, so this site might have the fewest birds. In summer, one may see terrestrial birds such as pipits or Rock Ptarmigan, but little else; in winter, numbers of birds probably are very low. However, some individual eagles and gulls occasionally fly over the area in a seemingly random fashion, as they do over most areas on the island.

Landfill: It is northeast of town and is sandwiched between the coastline and a steep hillside. Up to 300 eagles are counted here alone during the Christmas Bird Count (M. Jacobson, in litt.). Although this is not being considered as a probable windfarm site, we caution that the potential for interactions between birds and a windfarm might be high anywhere near here.This preliminary assessment suggests that the potential for bird interactions might be moderate or high at Sites 1–4 and near the landfill. It also suggests that the potential for bird interactions might be lower at Site 5.

Appendix D – Assumptions for Economics

Wind power costs;

These costs were estimated using available quotes, industry data and practical experience. Formal quotes were not obtained. Allowances were made in wind turbine and tower costs for the large increase in raw steel prices if the quotes were over 12 months old. Wind turbines w/standard tower currently cost ~$900/MW, for large machines, while smaller machines are more than double this. Shipping large components, with fragile parts such as blades is expensive. Cranes capable of the high, heavy lifts

Shipping

Based on past quotations and standard US shipping rates from the following factory locations: shipped to Dutch Harbor:

GE: various location in lower 48, delivered to Port of Seattle

Vestas: via ocean from Denmark

Fuhrlander: Port of Seattle, after importation from Germany

Engineering/Project Management

The estimates were derived from past jobs conducted by NPS in Alaska and using industry standard assumptions for the required tasks.

Foundation

All foundations were assumed to be standard ballast style. P & H style foundations were not considered as they require deep excavation. The sites were assumed to contain rock, and may need blasting, drilling. Concrete will be required, even if rock anchoring is incorporated

Electrical & Collection System

Normal conductors, and trenching estimates were considered. Allowance of between 3000’ and 4000’ of conductor per turbine were assumed. Allowance for transformers, vaults, and substation were included.

Installation & Commissioning

Commercial rates for contractors, assumptions for crane rentals starting at a Seattle facility. costs also included lodging.

Annual Maintenance

Estimated maintenance includes scheduled and unscheduled needs. This includes Items such as:

- site inspections
- oil changes
- warranty specific requirements (factory service)

These are industry estimates, and have been adjusted to meet the configuration and type of turbine technology for each scenario. It was also assumed that Unalaska equipment maintenance staff can and would be trained to provide regular service.

Data Collected from the City of Unalaska

RECVD	FORMAT	DATE	AUTHOR	TITLE	LONG TITLE
CITY	HARD COPY	May-99	DAMES&MOORE	FINAL REPORT - WIND ENERGY FEASABILITY STUDY	FINAL REPORT - WIND ENERGY FEASIBILITY STUDY - NAKNEK AND UNALASKA, AK - FOR THE STATE OF ALASKA - DEPARTMENT OF COMMUNITY AND REGIONAL AFFAIRS - DIVISION OF ENERGY
CITY	HARD COPY	Dec-93	CH2MHILL	WIND DATA - SUMMER DEPLOYMENT JUL-AUG 1993	CIRCULATION STUDY OF UNALASKA BAY AND CONTIGUOUS INSHORE MARINE WATERS - SUBMITTED TO HARBOR CIRCULATION STUDY WORKING COMMITTEE - FIELD DATA: SUMMER DEPLOYMENT (JULY-AUGUST 1993) WIND DATA
CITY	HARD COPY	May-94	CH2MHILL	WIND DATA - LONG TERM DEPLOYMENT AUG-DEC 1993	CIRCULATION STUDY OF UNALASKA BAY AND CONTIGUOUS INSHORE MARINE WATERS - SUBMITTED TO HARBOR CIRCULATION STUDY WORKING COMMITTEE - FIELD DATA: LONG TERM DEPLOYMENT AUGUST - DECEMBER 1993 - WIND DATA
CITY	HARD COPY	May-94	CH2MHILL	WIND DATA - WINTER DEPLOYMENT JAN - FEB 1994	CIRCULATION STUDY OF UNALASKA BAY AND CONTIGUOUS INSHORE MARINE WATERS - SUBMITTED TO HARBOR CIRCULATION STUDY WORKING COMMITTEE - FIELD DATA: WINTER DEPLOYMENT JANUARY - FEBRUARY 1994 - WIND DATA
PUBLIC WORKS	HARD COPY	Oct-95	STEIGERS CORP & RTP ENVIR ASSOC	REVISED PERMIT APPLICATION FOR PSD - FOR DUTCH HARBOR POWER PLANT	REVISED PERMIT APPLICATION FOR AIR QUALITY PROGRAM - PREVENTION OF SIGNIFICANT DETERIORATION (PSD) AND AIR QUALITY CONTROL - PERMIT TO OPERATE - FOR THE DUTCH HARBOR POWER PLANT - DUTCH HARBOR, ALASKA - STATE OF ALASKA - DEPARTMENT OF ENVIRONMENTAL CONSERVATION
CITY	CD	Dec-03	CITY	UNALASKA TOPO	CD#1: UNALASKA TOPO
CITY	CD	VARIOUS	VARIOUS	AERIAL PHOTOS - CROWLEY & UNALASKA CAD DWGS - CITY PROPERTY & CITY ZONING	CD#2: CROWLEY OSI 1.JPG; UNALORTH10.JPG; CAD-MAPZONING03.DXF; CITYPROPERTY.DXF
PUBLIC WORKS	HARD COPY	Mar-94	ENVIROMETRICS	RESPONSES TO ADEC COMMENTS ON PSD APPLICATION	RESPONSES TO ADEC COMMENTS ON PSD APPLICATION - DUTCH HARBOR POWER PLANT
PUBLIC WORKS	HARD COPY	Jun-98	RTP ENVIRONMENTA L ASSOC	FOURTH QUARTER MONITORING REPORT - FEB THROUGH APRIL 1998	FOURTH QUARTER MONITORING REPORT - FEB THROUGH APRIL 1998 - DUTCH HARBOR POST CONSTRUCTION MONITORING PROJECT - UNALASKA, AK - PREPARED FOR ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION AIR QUALITY MAINTENANCE SECTION
PUBLIC WORKS	HARD COPY	Jun-96	RTP ENVIRONMENTA L ASSOC	FIRST QUARTER MONITORING REPORT - JUN 16 THROUGH SEPT 30, 1995	FIRST QUARTER MONITORING REPORT - JUN 16 THROUGH SEPT 30,1995 - DUTCH HARBOR OZONE MONITORING PROJECT - UNALASKA, AK - PREPARED FOR ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION AIR QUALITY MAINTENANCE SECTION
PUBLIC WORKS	HARD COPY	Sep-92	ENVIROMETRICS	DUTCH HARBOR POWER PLANT - PSD APPLICATION	DUTCH HARBOR POWER PLANT - PREVENTION OF SIGNIFICANT DETERIORATION APPLICATION
AIRPORT MAINTEN ANCE	HARD COPY	Mar-00	USDOT - FAA	PROROSED CONSTRUCTION OR ALTERATION OF OBJECTS THAT MAY AFFECT THE NAVIGABLE AIRSPACE	ADVISORY CIRCULAR - AC 70/7460-2K PROROSED CONSTRUCTION OR ALTERATION OF OBJECTS THAT MAY AFFECT THE NAVIGABLE AIRSPACE
AIRPORT MAINTEN ANCE	HARD COPY	Dec-03	CODE OF FEDERAL REGULATIONS	77.23 STANDARDS FOR DETERMINING OBSTRUCTIONS	14 CFR - CHAPTER 1 - PART 77 77.23 STANDARDS FOR DETERMINING OBSTRUCTIONS
AIRPORT MAINTEN ANCE	HARD COPY	Dec-03	CODE OF FEDERAL REGULATIONS	77.25 CIVIL AIRPORT IMAGINARY SURFACES	14 CFR - CHAPTER 1 - PART 77 77.25 CIVIL AIRPORT IMAGINARY SURFACES

AIRPORT MAINTENANCE	HARD COPY	Dec-03	USDOT - FAA	FORM - NOTICE OF ACTUAL CONSTRUCTION OR ALTERATION	FAA FORM 7460-2 FOR ADVANCE NOTICE OF CONSTRUCTION OR ALTERATION NOTICE OF ACTUAL CONSTRUCTION OR ALTERATION
AIRPORT MAINTENANCE	HARD COPY	Dec-03	USDOT - FAA	FORM - NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION	FAA FORM 7460-1 NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION
PUBLIC WORKS	HARD COPY	Feb-01	GOLDER ASSOC	SET OF 8 DRAWINGS PLAN & PROFILES - EAST POINT & BALLYHOO ROAD TESTHOLES	FIGURE A01,A06,A11,A16,A22,A26,A31,A36
PUBLIC WORKS	HARD COPY	Apr-01	GOLDER ASSOC	SET OF 3 DRAWINGS TEST PIT LOCATIONS	FIGURE 2 - TEST PIT LOCATIONS EAST POINT ROAD FIGURE 4 - TEST PIT LOCATIONS BALLYHOO RD & ALASKA SHIP SUPPLY AREA FIGURE 3 - TEST PIT LOCATIONS BALLYHOO RD & CITY DOCK AREA
ELECTRIC UTILITY	HARD COPY		ELECTRIC UTILITY	UNALASKA ONE LINE DIAGRAM	UNALASKA ONE LINE DIAGRAM

Appendix F – Turbine Operation in Cold Climes

This section has been included as an informative discussion of wind turbine operation in cold and energetic sites. Northern has years of experience in these more difficult climates, and has carried out formal studies considering the issues of cold weather and involving the comparison of the particular turbines mentioned.

NOTE: The following discussion was prepared for a previous exercise, and covers wind turbines smaller than what The City is considering, it has been included as an appendix to offer further insight and better perspective for the City of Unalaska, and is not intended to specifically cover Unalaska.

In addition to high winds and speeds, prolonged cold temperatures represent a challenge for wind turbines. Significant wind energy occurs during these low temperatures. If a machine cannot harvest this low temperature resource, the value of the project is considerably reduced. For the machine, increased fatigue stress on components, over power due to exceptionally dense air, and difficulties with turbine lubricants all contribute to turbine operational problems. Moreover, subzero conditions make servicing and maintenance of some turbine models all but impossible, resulting in reduced turbine availability during cold periods and potential safety issues for operators trying to service the machines.

Although most manufacturers provide minimum operating temperature specifications in their technical documents, some companies only provide this information upon request. Even when minimum operating and/or survival temperature information is provided, very few turbine manufacturers back this information up with empirical data collected from tests in cold chambers, or actual experience. Consequently, a given turbine's proven experience in cold regions becomes the best gauge of machine performance. Both the AOC15/50 and NW100 turbines have significant cold weather performance track records in Alaska and above Arctic Circle, while the Fuhrlander and Norwin turbines have none that we are aware of beyond intermittent cold soaks in Northern Europe.

Of the turbines considered for this evaluation, the Atlantic Orient turbine has the longest track record with regard to operation in arctic climates, with multiple machines in operation in both Wales and Kotzebue, Alaska and additional machines installed in Russia and Canada. Northern Power Systems has had one NW100 operating successfully for three winters in Northern Vermont (with temperatures as low as -25° C) and one NW100 operating in Kotzebue, above the Artic Circle since spring 2002, which has experienced -50° C along with the AOC machines installed at Kotzebue.

Air density also plays a major role. Coastal high density, cold air is more dense, and contains more energy, therefore increasing performance Seasonal cold temperatures may allow the machines to run much higher on the power curve.

Mechanical Drive Train

A significant problem with wind turbines in cold regions relates to fluids in the mechanical drive train, most specifically in the turbine gearbox. With the exception of the NW100, all of the turbines considered for this evaluation utilize asynchronous induction generators with oil-filled gearboxes. *(Note the Vestas V47, GE 1.5 are also gearbox machines)*

The high rotational speeds encountered in turbines with asynchronous induction generators require constant lubrication in gearboxes. As temperatures fall below -20° C (-4°F), difficulties with gearbox oil can become a major concern if not addressed. Even in less severe climates many gearbox failures in the industry have been attributed to this problem. As a result, heaters are typically fitted to gearboxes, providing correct operating temperatures, and an additional level of complexity, or potential failure.

The limitations of gearboxes in arctic or cold climates were a key reason for NREL's move to support the development of the direct drive technology in the NW100. In addition to several power quality advantages discussed below, the use of a variable speed direct-drive generator eliminates a gearbox in a turbine's drive train, which theoretically increases a turbine's reliability and decreases a turbine's long-term operation and maintenance requirements.

Rotors

A rotor is the unit made up of the individual blades and hub. All of the machines have three bladed rotors and are stall regulated. Stall regulation is the simplest type, whereby the blades are at a fixed pitch, and do not actively move as the conditions change. Active pitch is often used on larger machines, although the added cost, complexity is not desired for small machines that do not gain enough extra energy to account for it. *(Note: Vestas V47, and GE 1.5 are active Pitch)*

The machines are often offered with an optional rotor diameter for either low or high wind speed sites. An energetic site could cause damage to machines with large rotors (which have a greater swept area) that would be subject to extreme forces. Manufacturers will not warranty equipment if they believe it will not be able to withstand site conditions. As such, due to the high wind speeds and challenging conditions at the site, the Norwin 225, FL100 and FL250 machines were compared using smaller rotors, i.e. we have assumed smaller 27m, 19m and 27m rotors for each machine respectively as would be mandated by the manufacturers instead of the standard 29m, 21m and 29.5m rotors.

Braking Systems

In addition to gearbox issues, brake type may also impact the turbine reliability, and must be evaluated. The turbines being considered have several different types of braking systems: electro-dynamic, blade airfoil pitch, shaft mounted disc, gearbox mounted disc, and blade tip brakes. Ideally brakes should be simple, protected (rather than exposed to the environment such as ice), and operate smoothly to limit stresses on the turbine machinery. The NW100 has two independent braking systems, a proprietary electrical dynamic braking system and an internally mounted disk brake system on the main shaft. The NW100 breaking strategy is an important difference, in that the exposed mechanisms existent in the other break types, which are difficult to service, subject to the weather, and can, reduce turbine reliability. Atlantic Orient has had difficulties with their electro-magnetic tip brakes and rotary transformer. Although improvements have recently been made, the Fuhrlander and Norwin machines, which use blade brakes (where the very end of each blade can be pivoted to increase drag), may encounter problems in the challenging mountain environment.

Towers

Tubular towers have the distinct advantage of aesthetic appeal, reduction of avian interaction (tubular towers do not provide a bird roosting place while lattice towers do), and sheltered ascent for service. These advantages are at the expense of overall weight, and therefore cost. The NW100, FL100 and FL250, and the Norwin 225 currently specify tubular towers. The drive trains of these turbines are also completely enclosed within a nacelle, allowing protected access to the turbine at any time. Atlantic Orient uses steel lattice towers. These tower options are lighter in weight, less expensive and require a smaller crane to install than tubular towers. However, maintenance and repairs are made at the top of the tower while unprotected and exposed to the elements. This may mean that repairs are unable to be made in a safe and timely manner, increasing the mean time to repair (MTTR), and thus decreasing the availability of the turbines.

It is important that Unalaska consider the advantages of tubular towers. For several reasons; Aesthetics, (the potential for a specific tubular tower permit requirement made in regard to: avian issues), visual impact, and safety issues (such as preventing unauthorized climbing of lattice structures) along with the basics of ease of service and maintenance gained with a fully enclosed nacelle and tubular tower.

VAR, Frequency and Voltage Support

The turbines considered are of two electrical architectures: fixed speed with induction based generation, and variable speed synchronous generation. Both types have advantages, and disadvantages, but certain site conditions may impact the choice. Wind turbines using induction generators absorb some reactive power but generate real power. The resulting positive real power (kW) and negative reactive power (kVAR) contribution to the grid skews the ratio of real to reactive power and causes a reduction of the total power output and power factor. If not corrected with the use of additional capacitance, and/or switched capacitance banks, this can cause the local distribution system to run below rated power factor during periods of high wind and low load. With the exception of the NW100, which employs a variable speed synchronous generator connected to the grid through an inverter which can produce real power and offers power factor control, all of the turbines considered in this evaluation utilize induction generators. *(Note: Vestas V47 is a basic induction machine, while the GE 1.5 does have an inverter link, providing power quality advantages, though not as clean as direct drive technology)*

The smooth starting characteristics (avoiding high inrush current), and ability to possibly bolster this part of the grid through reactive power output, may give the variable speed–synchronous topology of the NW100 an advantage.

Turbine Orientation (Upwind/Downwind)

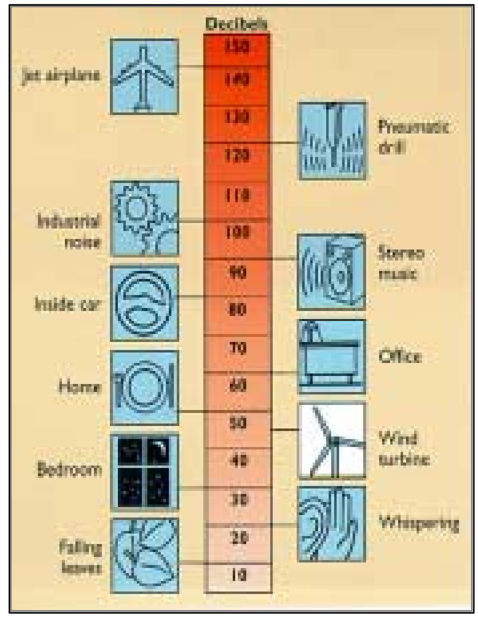
Of the five turbines reviewed all are upwind except the Atlantic Orient AOC 15/50. Upwind wind turbine blades catch the wind ahead of the actual turbine (like a propeller facing into the wind). In the case of the AOC turbine, it uses passive free-yaw downwind technology (the blades are downwind of the actual turbine and tower). The Norwin, NW100, and both Fuhrlander machines all operate in the upwind orientation and require a yaw motor to position the turbine into the wind. This adds an area of potential malfunction, but having demonstrated high reliability over years of operation it is now present on the vast majority of wind turbines of medium and large sizes. The AOC machine's passive free yaw downwind technology although perceived as a simple alternative to upwind active yawing, has several disadvantages:

- Turbulent winds can cause high yawing rates, and the machine can also become stuck in an upwind position only to be yanked violently into downwind position – both can potentially cause catastrophic bending moments in the rotor blades, bearings, shaft and even the tower.
- The droop cables on the turbine must be manually unwound, requiring additional scheduled maintenance.
- Fatigue due to a phenomenon known as "tower shadow", which occurs because the airflow around the tower is altered before it meets the swept area of the turbine. This fatigue is evidenced by a characteristic noise when the rotor's blades sweep past the tower.

In summary, we believe that active yaw technology using motorized yaw drives is a superior design. Fuhrlander, Norwin and the NW100 incorporate this design, and this approach is used exclusively on all larger machines. *(Note: The Vestas and GE machines are upwind, active yaw)*

Noise

Public opinion on noise output from a wind turbine is often quite subjective. However, noise test standards determining relative levels of noise emissions from a particular machine do exist and are regularly evaluated in the industry.



Turbine Decibel Level Comparison to Common Sounds

The basic contributors to noise are: 1) blade-tip –"whistle", 2) generator - "hum", and 3) rotor –"whoosh". All three of these can vary from machine to machine. In the case of the four machines evaluated, the AOC will be the "loudest" as it has tip brakes that can whistle, an exposed generator that will emit a hum in windy conditions, and as a downwind machine, will emit a tower induced pulse noise as the blades sweep by. The Fuhrlander and Norwin machines, which are of similar design to each other, will emit some blade tip noise as they have blade brakes, although different than the AOC tip brakes. Norwin and Fuhrlander will also emit some generator and gearbox noise although muffled as they have nacelles covering these components. The NW100 will be the quietest, as it has no blade or tip brakes to whistle, and its low speed generator is almost silent.

Warranty

Norwin and Northern Power Systems offer a two-year standard warranty. AOC and Fuhrlander offer only one-year coverage as standard. This is a significant difference, because a turbine manufacturer's ability to deliver, warranty, and support their product is a critical consideration in the current climate in the wind industry. Changes in the market, as well as fluctuations in incentive programs have put the financial viability of some manufacturers in question, and the small number of manufacturers offering medium size machines continues to put pressure on these smaller firms to be careful with warranty and service offerings. In addition, the liability and logistical difficulties that are necessary for supporting small numbers of machines in remote or distant areas can be difficult. With that said, the four manufacturers considered are standing solidly behind there product, and tend to be realistic about warranty costs and service requirements.

The Unalaska site is rough: it has high wind gusts, a very high annual average wind speed, icing conditions, is cold and has turbulent winds from the complex terrain. These site conditions will cause any turbine manufacturer to be concerned. Unalaska will want to ensure the warranty provisions are clear, and do not allow loopholes because of these conditions. Conversely, Unalaska should provide all available data to the manufacturers to assure that the manufacturer has prepared the turbine to withstand this site.

Service

While not researched in detail, a short section on service is included. As already discussed, there are few turbines of this size range to support a formal service entity in close proximity to the site. The large wind farms just now sprouting up in Oregon have a service staff, but typically are not trained on smaller machines. Norwin and Fuhrlander currently rely on factory personnel in Europe for major service, and/or training. AOC staff is based in Prince Edward Island, Canada. While Northern Power has service staff based at the NWTC in Boulder, Colorado and in Vermont, and will have trained technicians via an Alaskan utility.

All of the machines will require a factory trained service at least once a year, typically twice per year while under warranty. Training will typically be conducted during these periods, allowing the Unalaska Staff to become proficient and therefore able to perform regular checks, lubrication, and basic service.

Appendix G – Wind-Diesel Integration

Wind-Diesel Hybrid System Fundamentals

Introduction

Wind power can be a beneficial energy source for many communities. Remote villages and island communities that are isolated from a large electrical grid, typically depend solely on diesel generators for their electrical needs. These communities often pay a high price for power due to the cost of transporting fuel and maintaining small isolated power stations. The successful addition of wind power can reduce fuel and maintenance costs at these power stations, resulting in lower energy costs. In addition, wind-diesel hybrid systems produce a significant amount of excess energy, herein defined as a secondary load, which is typically converted into heat for productive use in the community. Finally, although wind-diesel hybrid systems are disconnected from a large electrical grid, these power systems are designed to maintain utility grade reliability and quality.

Successful wind-diesel hybrid system performance is related to several factors including:

- Site specific wind characteristics, including daily and seasonal variations
- Site wind speed turbulence intensity
- Electrical demand and its correlation with high wind speed
- The minimum operating power levels of the diesel generators

When designing a wind-diesel hybrid power system, a variety of options and system architectures are evaluated based on the factors outlined above and the operating features desired by the community. The size of the load, the practical size and number of wind turbines, the possible uses of the secondary load energy for heating or air conditioning purposes, and the amount of time that a system is desired to operate in a wind-only mode (with all diesels turned off), together define the hybrid system design. Below we present several different wind-diesel hybrid system architectures and explain some of their key components.

System Overview

The primary components of a wind-diesel hybrid power system include:

- Diesel generators
- One or more wind turbines
- A synchronous condenser or rotary converter and battery bank
- Secondary loads

- Engine and wind system controllers

We define wind-diesel systems as being either low penetration or high penetration based on the amount of installed wind capacity as compared to the average load from the community.

Modern wind turbines are available in a variety of sizes between 50 kW and 1500 kW for a wind-diesel system.

Low Penetration Hybrid Systems

In a conventional diesel power system the generator power level follows the demanded load. If more than one generator is on line, the load is shared in proportion to the rated power of each generator. The engine speed governor controls fuel to the engine to regulate it to its rated speed, and consequently the generator's frequency to 60 Hz. A balance of mechanical and electrical power occurs at the generator; as load demand and generator electrical load increases, the shaft mechanical torque increases, which tends to reduce shaft speed and generator frequency. The governor responds by increasing fuel to the engine to maintain speed and frequency, increasing mechanical power at the generator shaft to follow the demand of the electrical load. The engine, governor, actuator, and fuel distributor represent a stable closed loop control system to regulate frequency. Field experience has proven the stability of this control loop.

When a small amount of wind power is added to a system, the engine governors adjust to the reduced load; tolerating the small contribution provided by the fluctuating wind power. This mode of operation is acceptable until the installed turbine capacity exceeds 15% to 30% of the load demand. This operating scenario is defined as a low-penetration hybrid system.

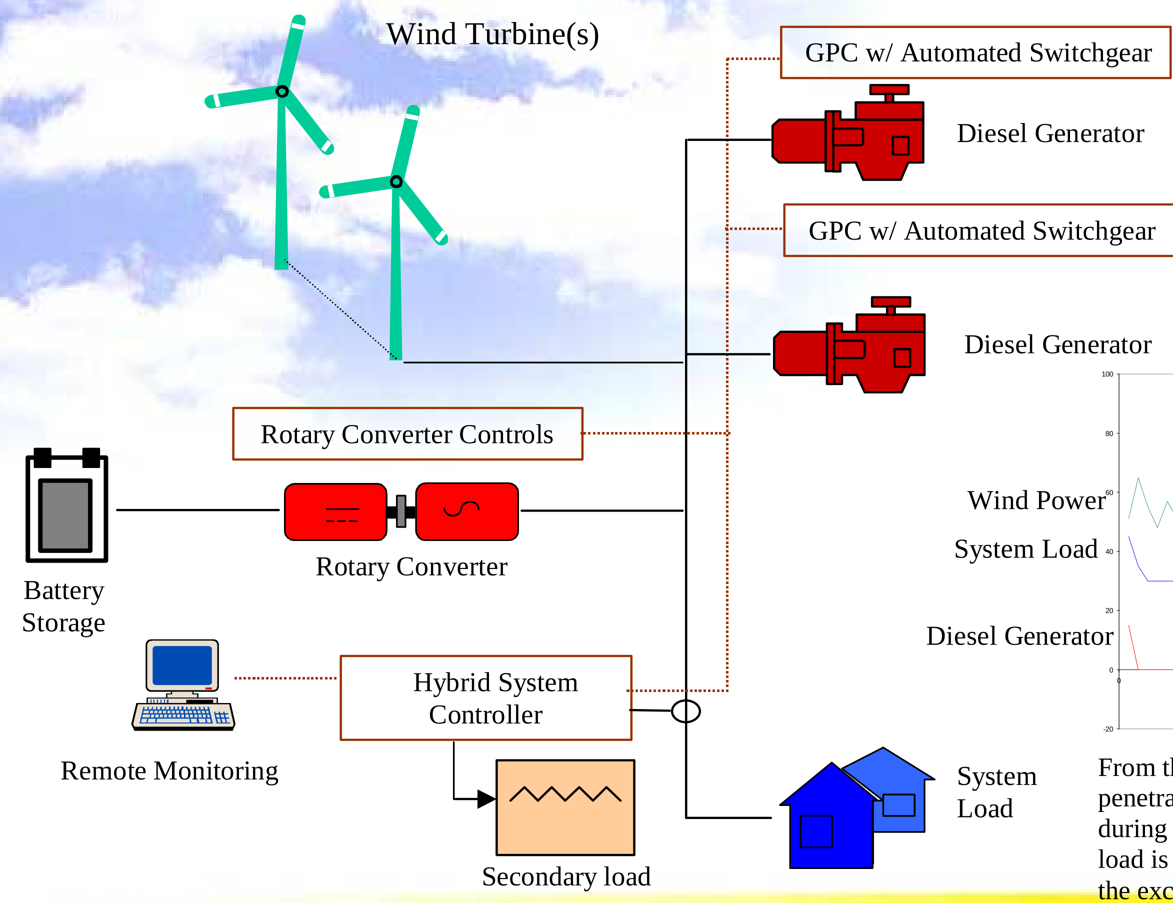
High-Penetration Hybrid Systems

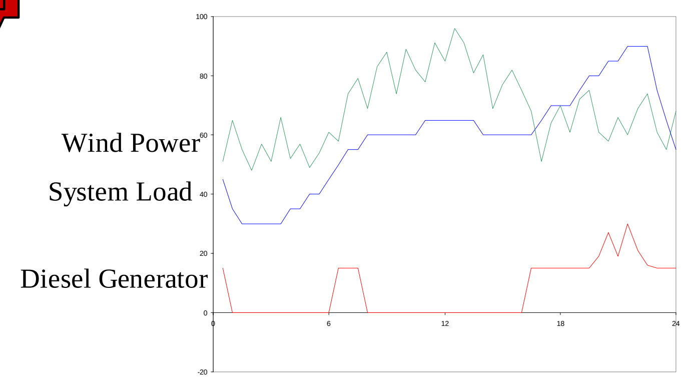
When the installed wind capacity exceeds 20% - 30% of the load demand, the uncontrolled wind power begins to play havoc with the engine governors and dispatch control. As installed wind capacity is increased, peak wind power could potentially exceed the load demand on occasion, causing the engines to be back-driven and the system to become unstable. This occurs because induction generator wind turbines contribute power according to the wind passing the rotors, irrespective of load demand. In addition, the variability of the wind often creates large power fluctuations over short time periods. Consequently, a wind-diesel system must increase or reduce diesel-generated power quickly to accommodate the wind power and keep frequency constant. Since the diesel can't absorb excess wind turbine power, frequency control requires the addition of an active load element, herein defined as a secondary load. This additional wind power influence, the active load element and a closed-loop control circuit complicate the system and provide opportunity for control loop interactions and unstable operation.

In a remote island power system, stability is power quality as defined by the constancy of voltage and frequency of the electric power produced. High penetration wind-diesel systems are inherently unstable and require active control to make them work at constant frequency. The challenge is the large uncontrolled power source presented by the induction wind turbine. To meet this challenge a synchronous condenser or rotary converter must be included in the hybrid configuration to provide reactive power (VAR) support for the induction (asynchronous) wind turbine generators. A sample 1-line pictogram of a high-penetration wind-diesel hybrid configuration is presented below.

A rotary converter combines the function of a synchronous condenser and a power converter, allowing power to be transferred to and from a DC and battery bank. The main advantage of incorporating a rotary converter in a hybrid system is that the margin required to operate in a wind-only mode is reduced. Without the battery storage provided by a rotary converter, the variability of wind and the consequent variability of power supplied by the wind turbine(s) will prevent the diesel generators from shutting down, often even during periods of high wind.

Sample High-Penetration Wind-Diesel Hybrid Architecture





From this graph we see that with a stable high-penetration architecture, the diesels can turn off during intervals with high wind. The Secondary load is called upon during those periods to "dump" the excess energy generated by the wind turbine.

Secondary and Optional Loads

As discussed above, high-penetration hybrid systems require some form of load element to accommodate the excess energy in the system during periods when wind generated electricity exceeds the load. The secondary load or “dump” load must always be on-line in the system to absorb any energy that is in excess of the system load at any time. For example, the dump load may heat water that can be used for space heating. Another way to accommodate excess energy in the system is with the addition of optional load air conditioners. Optional load heaters are different from the secondary or “dump” load in that they are located within the local grid, are thermostatically controlled, and consequently can be overridden when heating is not needed. Optional load heaters are only available for use when there is excess energy available in the system.

An optional load heater placed in a school or other public building can serve to reduce fuel costs during winter months during periods when wind energy exceeds the local load. If the wind power exceeded the load during such a period, the secondary water heater would be called upon to make up the difference between the load demand and the wind power output. Secondary load heaters in general must be placed near the power plant. The economics of wind-diesel hybrid power systems are often very favorable when a value is placed on this secondary load heat.

Modes of Operation

Most wind-diesel hybrid power systems have the ability to operate in three distinct modes:

- Diesel-only mode
- Wind-diesel mode
- Wind-only mode

Diesel-Only Mode

In the diesel-only mode of operation, the power system will function as a typical diesel generator providing the electrical load with the diesel generator controls providing the frequency and voltage regulation. The optional load unit heaters are recommended in order to maintain minimum operating levels (25 % of rated diesel power). At most locations appropriate for incorporating wind, operation in the diesel-only mode is infrequent.

Wind-Diesel Mode

In the wind-diesel mode, the wind turbine and the diesel operate in parallel. The electrical power from the wind turbine and the diesel generator are combined to provide power to the grid. Voltage and frequency regulation are provided by the diesel generator controls assisted by the system secondary load controller.

In this mode it is anticipated that there will be an abundance of heat energy provided to the optional heat load and secondary load. The amount of optional and/or secondary load will be equivalent to the instantaneous energy produced minus the electrical demand by the village. Essentially the secondary load provides the energy balance to maintain system frequency stability without unloading (or negatively loading) the diesel engine.

Wind-Only Mode

When there is sufficient wind energy for the wind turbine to carry the entire electrical load and provide an adequate margin to account for the variation in the wind speed and anticipated variations in village load, the diesel engine can be shut down. When the diesel is shut off, the synchronous condenser (or rotary converter) provides reactive power to the grid to maintain voltage stability. The secondary load controller communicates with the secondary heaters so that the system frequency does not deviate.

The amount of time that a system can operate in each mode will fluctuate and is based on:

- The average wind speed.
- The wind speed variation, measured as turbulence intensity and causing the turbines power output to vary.
- The average electrical load and the variation of that load.
- The allowable margin, defined as the amount of wind energy in excess of the load power required. An average - positive margin is required in a system to insure frequency stability. The average wind power must exceed the utility demand (during Wind Turbine Only mode) or the spinning components will slow down and the frequency of the system will drop.

One of the obvious goals of a wind-diesel hybrid system is to minimize the run-time of the diesel generators. This can occur when a sufficiently steady wind can allow the wind turbines to carry the primary loads. However, the reality of a wind-diesel hybrid power system is that often times there is sufficient wind to carry a system load, but the variability in the wind is such that the diesels are not allowed to completely turn off. During the design phase of a wind-diesel project, Northern conducts modeling activities whereby we specify a minimum diesel run-time to avoid scenarios where diesels are required to turn on and off in short time intervals. As a result, it is typical to conduct modeling scenarios where a system is sized so that wind provides over 90% of the energy demand, yet the variability in the wind keeps the diesel facility operating over 90% of the time as well. The uncontrolled nature of wind power simply does not allow for wind-only mode except during the rare wind events.

As a rule of thumb, the installed wind capacity needs to be over twice the average load if significant wind-only periods are desired. The incorporation of a rotary converter and battery bank will compensate for this variability and result in significant wind-only time.

Powerhouse Requirements and Layout

The addition of wind power into an existing diesel facility would require the integration of several hardware components and control cabinets inside a community's powerhouse. Space would be required for a synchronous condenser or rotary converter and their controllers, a battery bank, a wind-hybrid system controller, and the secondary load controller. The control cabinets will need to be located in an enclosed area preferably in close proximity to the engines, and synchronous condenser or rotary converter. In addition, the secondary load heater should be located as close to the powerhouse as possible to ensure a quick response between the chiller/heater and the secondary load controller. If there is no existing facility, then considerations will need to be made for a new powerhouse, switchgear and a diesel genset.

Overview of Costs

In general, wind-diesel hybrid power systems cost between US$1,600 - US$2,800 per installed kilowatt of wind capacity. Wind turbines in the 50kW - 250kW size range cost between US$1,800 - US$3000 per kilowatt. The engine(s), engine controls, secondary load heaters and the system integration make up the balance.

Appendix H – About Northern

As a technology-neutral Engineering, Procurement and Construction (EPC) contractor providing high reliability electric power systems for commercial and industrial customers, we are confident of being able to offer you the highest quality and value for this project.

Founded in 1974, Northern Power Systems has installed more than 800 systems in 45 countries on all seven continents. We have long-term experience in project management, from preliminary site assessment and economic modeling, through design and fabrication, to system installation, commissioning and personnel training. Northern has a long history of getting the job done on budget, on time, and within specifications. We have been a pioneer in matching appropriate turbine technology to specific project site conditions, and we regularly partner with the leading turbine manufacturers in the world including NEG Micon, Vestas, Fuhrlander and GE Wind among others. Our unparalleled track record in the renewable energy industry was underscored when former U.S. Assistant Secretary of Energy for Energy Efficiency and Renewable Energy, Dan Reicher, joined Northern Power Systems as Executive Vice President in 2001.

Northern's customers have included Bechtel, Cargill Dow, Chevron, Flour Daniel, PG&E, Hydro-Québec, the Woods Hole Research Center, AT&T, Newfoundland and Labrador Hydro, Johnson & Johnson, PEMEX, SC Johnson, SNC Lavalin, Suncor, Yukon Electric Corporation, various branches of the US Armed Forces, the National Renewable Energy Laboratory, and the National Science Foundation, as well as state and local governments.

Over the past 28 years, Northern has installed wind turbines throughout the world. The outstanding reliability of our wind projects is perhaps best highlighted by our turbines powering satellite communications at the South Pole, which have successfully operated for more than 15 years in winds up to 88.5 m/s (198 mph) and temperatures as low as -80º C. The range of our experience in the wind industry includes modeling and feasibility reports small and large wind farm projects, wind resource assessment and pre-development for commercial wind farms, wind turbine design and installation, including the HR3 (3.2kW), NW100 (100kW) and NW1.5 (1.5MW), the commercial integration of wind generators in remote hybrid isolated electric grids, and the development of power electronics for megawatt-scale variable speed, direct drive wind turbines.

Recent wind projects include:

- Feasibility Study for an 80 megawatt wind farm in Nebraska for Cargill Dow
- Installation of a Vestas V29 for the Tanadgusix Electric Corporation in St. Paul, Alaska
- Wind resource monitoring and predevelopment services for 60 MW wind farm in Vermont
- Installation of a NW 100 for the Kotzebue Electric Authority in Kotzebue, Alaska
- Feasibility study for a 250 kW expansion of a wind-diesel hybrid system for the US Navy on San Clemente Island, California
- Installation, long-term testing and analysis of two 600 kW wind turbines as part of the Advanced Research Turbine Program at the National Renewable Energy Lab in Boulder, Colorado
- Feasibility study of wind and other renewable energy sources for US Immigration and Naturalization Service border stations
- Assessment for installation of a 100kW wind turbine at the Woods Hole Research Center in Falmouth, Massachusetts
- Feasibility/Integration Study for American Electric Power (AEP)/e7 regarding a wind-diesel hybrid system in the Galapagos Islands
- Assessment for six 100kW wind turbines for the Alaska Village Electric Cooperative
- Wind resource assessment for Middlebury College for wind power at its Snow Bowl ski area

Northern's wide-ranging power industry experience beyond the wind energy sector also demonstrates relevant project management and technical capabilities. For example, in 2001, Northern completed an $18 million project for turnkey delivery of 113 power systems along a 1,000-mile oil pipeline running from the Caspian Sea to the Black Sea through Russia and Kazakhstan. For this project Northern met very stringent power reliability and quality assurance requirements of the prime contractor, Fluor Daniel, and the end customer, Chevron. This year, we commissioned a 1 MW combined heat and power system for an industrial customer in California, and we are completing installation of a 3.2 MW landfill gas-powered cogeneration project for SC Johnson in Wisconsin.

Northern adheres to a strict Quality Assurance process throughout all phases of each turnkey project. We have been reviewed and approved by multiple government and private sector clients and are widely recognized throughout the industry for the quality of the systems that we install and support. Northern's quality procedures conform to ISO-9001 guidelines.

