Best Practices in Implementation of WIND-DIESEL SYSTEMS

Model Wind-Diesel Provisions and Due Diligence Guidelines for the Development of Sustainable WIND-DIESEL SYSTEMS

Denali Commission — 10 Years Of Progress 1998-2008 — Alaska

Alaska WiDAC Wind-Diesel Applications Center

ACEP Alaska Center for Energy and Power

Cover photo of St Paul Island courtesy of TDX Power.

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Abstract

There are numerous best practice documents available for wind energy developers. However, there is no such document in existence for isolated wind-diesel (W-D) systems which, in addition to being more complex from a technical standpoint, also deal with more unique climatic issues and logistically complex challenges in Alaska. The basis for this work is the need for a clear understanding of the likely effects of high wind penetration on electricity systems, identification of the issues that limit the ability to achieve Alaska's stated aims for wind generating capacity, and determination of the potential courses of action – with appropriate timescales – for realizing a significant wind energy portfolio in the generation mix.

This Best Practices document ("Guidelines") highlights those practices that have demonstrated the greatest success and provides recommendations on the courses of action that are meant to be practical but also, by necessity, need to be general, in the implementation of W-D projects. Using a set of predetermined criteria, the Guidelines will serve as a *de facto* best practices guide that developers can use to ensure that projects are evaluated against a consistent set of standards.

The recommended practices address site selection and access (ground, transmission lines), foundation design, turbine selection, energy storage, permitting practices, environmental impact, property values, project performance standards, and public safety and health considerations. Unless there is a clear best practice identified in each of these areas, the Guidelines presents options and highlights the benefits and shortcomings of each.

Disclaimer

Contents

PART II: RECOMMENDED BEST PRACTICES FOR PROJECT PLANNING AND INTEGRATED RESOURCE ASSESSMENT

PART III: RECOMMENDED BEST PRACTICES FOR SITE DEVELOPMENT AND OPERATIONS

NOTE: Appendices are not included in this Draft.

Foreword

Alaska is unique to the United States, yet it is not unique to the world. A low population base along with a largess of publicly managed financial and natural resources sets Alaska aside from third-world countries. Yet similar to villages in struggling countries, rural Alaska communities often lack basic infrastructure such as plumbing and affordable energy, relying on expensive diesel resources. Those communities that benefit from access to a road system and more affordable heat and power face a crisis in available natural gas resource in the near future. For these reasons, renewable and alternative resources such as wind naturally enter the discussion. For Alaska, understanding that wind must be integrated with existing fossil fuel systems for them to work is fundamental. This integration is still being tested and can be complex from a geographic, technical, political and financial perspective.

Individuals, utilities and communities looking to introduce wind power into rural Alaska power systems face a potentially-daunting challenge. Newcomers to this technology often focus their attention solely on the wind turbine as this is the most visibly-distinct component in a wind-diesel power system, like a huge kinetic sculpture acting as a symbol of community action against rising energy costs. But wind turbines require careful planning, design, permitting and technical integration. Failure to appreciate the complex challenges ahead and the detailed processes that must be followed in any new installation almost guarantees that the project you envision will end up taking more time, upsetting community members and eroding away any potential financial benefits that were likely your primary motivation to pursue wind in the first place.

There is an old saying that “Experience is another word for mistakes.” Fortunately, others have come before you gaining experience the hard way. The lessons learned, both in Alaska and outside are being shared with you to be used as a “virtual tool box” to develop a better-performing solution in less time than your predecessors. Even if you plan to hire an engineering firm to manage your projects, this Best Practices Guidelines provides you with the knowledge and tools to contract out a better project. All aspects of your existing power systems must be scrutinized to determine if you are even ready for wind energy or if you need to first fix the basic foundation of your diesel generators and distribution systems. Site assessment for wind potential, environmental permitting and geotechnical considerations can highlight details that should be incorporated into your project design. Similarly, community involvement from conception through construction and commissioning can ensure a public that is eager to work with you and better appreciates the benefits of the project.

Failure to appropriately plan is risky and could result in the construction of an inoperable wind system, serving as a reminder of a project that was poorly planned and designed or was built and quickly decayed due to lack of maintenance. Successful projects require more planning up front, but address all aspects throughout the system lifespan – from conception through construction and on to maintenance and operation for 20 years or longer. The Guidelines will get you on the right path to the kind of project that will provide benefits for the present and for the next generation.

The Denali Commission (Commission) and the State of Alaska (State) together leverage federal and state financial and technical resources toward exploring energy options for Alaska. The Energy Policy Act of 2005 provided congressional direction to explore renewable and alternative options with federal funding. Consequently, the Commission and State co-funded the seed finances for what is today the Renewable Energy Fund (REF). Similarly, the two agencies have partnered on developing the Emerging Energy Technology Fund (EETF) to incentivize new technologies toward commercial readiness. Because wind resources are prevalent in Alaska, investment in predevelopment activities and tools, such as this guidebook, remain a focus.

With the common goal of successful wind-diesel energy, Alaska will continue to lead the world in wind-diesel technology. The University of Alaska is commended for identifying the need for this guidebook and competently carrying it through.

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Acknowledgments

This document presents ACEP's, and in particular, WiDAC's position on the major principles of implementing W-D systems in Alaska and considers factors that may foster sustainable integration of renewable power in the generation mix. This peer review draft aims are to encourage discussion, to initiate changes where they are needed, and eventually lead to a robust document that will provide practical guidance, in the form of Best Practice Statements, in implementing wind-diesel projects in Alaska.

There are few Best Practice Guidelines for W-D systems in circulation, partly because of the uniqueness of this industry as well as its novelty. Recognizing the universality of the challenges faced in the development of wind power systems, this Guidelines builds on the experience gained both here and abroad by various wind industry players in producing their own Best Practice Guidelines, including:

AWEA – American Wind Energy Association;
NWCC – National Wind Coordinating Committee;
BWEA – British Wind Energy Association;
AusWEA – Australian Wind Energy Association;
EWEA – European Wind Energy Association; and
CanWEA – Canadian Wind Energy Association.

It also builds on existing literature and on experience gained from wind-diesel projects already operating in Alaska, including AEA's *Best Practices Guide To Environmental Permitting and Consultations*, and REAP's *Community Wind Toolkit*. Some useful material specific to operation of isolated W-D systems has been obtained courtesy of Risø National Laboratory for Sustainable Energy, Denmark.

This work has been funded by the Denali Commission under the Emerging Energy Technologies Grant Fund as part of the joint effort to address issues specifically related to operation of W-D systems in remote Alaskan communities.

ACEP acknowledges the time, effort, experience and expertise of all those who continue to contribute to this document. The Guidelines is a living document that should be updated when significant developments in the technology or the market conditions and commercial activities occur. The present report is the first version. Please send your comments and contributions by email to the addresses on the inside front cover.

Glossary

Acronyms and Abbreviations

ACMP	Alaska Coastal Management Program
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
AEA	Alaska Energy Authority
AVEC	Alaska Village Electric Cooperative
EIA	Environmental Impact Assessment
EMI	Electromagnetic interference
FAA	Federal Aviation Administration
NCDC	National Climatic Data Center
NEMA	National Emergency Management Association
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Association
NREL	National Renewable Energy Laboratory
PF	Power Factor
PNL	Pacific Northwest Laboratory
PPA	Power Purchase Agreement
ROI	Return on investment
ROWs	Rights of Ways
SCADA	Supervisory Control and Data Acquisition
SHPO	State Historic Preservation Office
SLC	Secondary Load Controller
USACE	U.S. Army Corps of Engineers
USDOE	U.S. Department of Energy
USFWS	U. S. Fish and Wildlife Service
W-D	Wind-Diesel (System)
WMO	World Meteorological Organization
WRA	Wind Resource Assessment

1 Introduction

Background

Wind-Diesel Power Systems in Alaska

Development of wind-generated power holds the promise of significantly contributing to the sustainable energy portfolios for electric utilities in Alaska's rural villages, many of which are isolated from the Alaska Railbelt electrical grid intertie and from each other. With its potential economic and environmental advantages, wind power generation has become an accepted industry with several W-D projects operating in various Alaska communities.

Alaska represents one of the near-term markets for the implementation of wind-diesel systems, with operational systems at St. Paul and Wales providing strong field demonstrations of the technology. Factors spurring the market for wind-diesel applications in Alaska include:

- The high cost of fuel and fuel storage, and a strong push for locally supplied power sources;
- Alaska has more than 90 rural communities that are in areas with Class 5 to 7 winds (based on NREL wind resource maps) that are potentially suitable for wind energy development;
- Alaska's climate supports the concept of higher-penetration systems because any waste energy can be used for space heating; and
- Funding for projects is available through a number of federal and state government channels, plus native and private corporations.

The rate of growth of the wind industry in Alaska brings more people into closer proximity to the wind turbine generators, and it is important that any potential impact from future projects be well assessed.

Chapter Contents

1.1 Concept of Best Practice Guidelines

ACEP

The Alaska Center for Energy and Power (ACEP) was established in 2008 as a research center that operates under a private sector business model within the University of Alaska system, and one very important aspect of its work is to promote excellence in wind energy research and development.
ACEP's mission in part is to promote sensitive and appropriate uptake of wind energy by developing transformational energy technologies for widespread deployment in Alaska. In this regard, ACEP's vision is for a robust wind community that makes a significant contribution to a safe and reliable energy supply that is economically and environmentally sustainable.

WiDAC

WiDAC was formed in 2008 by founding partners ACEP, AEA, and NREL to support the broader deployment of cost-effective W-D technologies to reduce and/or stabilize the cost of energy both on an international level and specifically in Alaska's rural communities. The increasing global acceptance of W-D technology combined with the expanded need for intelligent grids, impacts of global environmental change, and economic uncertainly of continued sole dependence on fossil fuels in isolated communities, spurred the development of WiDAC as a dedicated program that can provide analysis, research, and an educational base for this new market area.

WiDAC is designed as a collaboration between industry and private sector developers and researchers, organized around a consortium of agencies, national labs, utilities, and private sector manufacturers and businesses involved in or supporting wind and wind-diesel projects in Alaska.
WiDAC has three primary areas of focus, including

1. Independent assessments of different energy options and development of new control strategies as necessary;
2. Technical support – serve as a resource to provide information needed to evaluate, implement, and operate optimized W-D systems;
3. Workforce development and education programs primarily focused on the implementation of wind, W-D and other renewable technologies.

WiDAC's current research agenda revolves around the following topic areas:

- Addressing high wind penetration challenges;
- Addressing harsh climate issues in implementation of W-D systems;
- Policies to overcome socioeconomic barriers to wind development;
- Information clearinghouse – support activities in wind education.

Principles Underpinning the Guidelines

Basis for the Guidelines

This *Best Practices in Implementation of Wind-Diesel Systems* (‘Guidelines’) reflects ACEP’s and WiDAC’s commitment to support and promote the sharing of good practices within the wind industry to enhance continued development of wind turbine generation facilities in Alaska. To encourage best practice within the industry, it is anticipated that the Guidelines will act as a reference document and provide practical guidance and recommendations to the main issues of which W-D power system developers should be aware when developing projects.

The need for this manual and its systematic use by those involved in W-D projects becomes clear when one considers the prevailing circumstances in Alaska: best practices for project implementation are missing in terms of[1]

- Overview of methodologies and tools;
- Documented examples of cases and potential locations;
- Functional outlines of guidelines based on practical experience; and
- Realistic implementation strategies aimed at market creation.

The purpose of the Guidelines is to encourage responsible and sensitive wind-diesel development that takes into consideration the concerns of local communities, planners, and other interested groups. Emphasis is on sustainable W-D system design for optimized power output, responsible environmental practices on aspects of development that affect external stakeholders, and on good community consultation practices.

The best practices set forth in the Guidelines are general and indicative only, not prescriptive. In their implementation, the following are noteworthy:

- Each site, community and development plan will be different; the Guidelines acknowledge that each wind energy development will be unique and will require assessment on its individual merits.
- The Guidelines are not intended to replace existing legislation, policy or regulations at local, state or federal government levels.
- The Guidelines are not intended to provide in-depth advice and guidance on all aspects of W-D systems in relation to the design, construction, commissioning, operation, maintenance and decommissioning; the Guidelines merely offer a set of principles and suggest a range of techniques that can be used.

[1] P. Lundsager, H. Bindner, N-E. Clausen, S. Frandsen, L. H. Hansen, and J. C. Hansen, “Isolated Systems with Wind Power,” *Technical Report*, Risø-R-1256(EN), Risø National Laboratory, Roskilde, Denmark. June 2001.

Target Audience

The Guidelines outlines the best practices designed to be practical and intended for use primarily by developers of W-D projects.
Besides serving as an aide-mémoire for developers, this Guidelines is also helpful to the wind community – proponents, manufacturers, research and development organizations, consultants, and members of the general public already involved with, or interested, in developing W-D system installations from small remote area power systems to large wind farms in Alaska.

However, the document is nonetheless relevant to all organizations (planners, Government departments/agencies, local organizations, non-governmental organizations and communities) contributing to the life cycle of wind-diesel project (from initial feasibility studies through to decommissioning) and particularly relevant to senior and operational management within organizations developing, constructing or operating W-D systems, or considering becoming involved in the sector.

Even if the document is not used on a regular basis for wind power projects, it shall have significant value as a repository of expertise for reference.

Specific Document Objectives

Overall, the Guidelines seek to identify, analyze and promote new best practices and policies to accelerate the dissemination of innovative and strategic state and regional activities in promoting the acceptance of wind. The objectives are:

1. Assist the efficient and sound development of renewable energy installations in Alaska by identifying the best practices and policies.
2. Develop a virtual toolbox that provides an internally complete set of guidelines that outline the key steps and considerations in the implementation of a high quality wind-diesel project.
3. Provide references to existing (successful) wind power projects in Alaska so as to enable policymakers create policies based on an assessment of the benefits of wind power projects in Alaska.
4. Serve as a template for future application-specific Best Practice documents that will provide more detailed information and examples.

This handbook gives a suite of informational material that relies on what has worked for existing projects in Alaska, the United States, Europe, and other parts of the world, and is descriptive only: it does not say "this is the only way to develop a project," rather it states, "this is the best way," or that "some agencies require this."

Future Guidelines Revisions and Extensions

This document is intended to be as internally complete as possible; however, it is not exhaustive, and as such it is designed to be flexible, allowing for modifications in the future as more local experience is gained or as amendments are made with regard to state and federal policy.
It is only a starting point – expansion of the document is envisioned as more experience is gained from the benchmark activity on ACEP's Wind-diesel Hybrid Test-bed, updated insight from recent wind power projects in Alaska, and from increased activity within the global wind energy sector.

A process will be developed to convert the Guidelines to a living document: ACEP will manage evolution of the Guidelines through the creation of a Wiki[2] at its website in a format that is open for review by a limited number of individuals associated with wind power systems in Alaska.

Implementing the Guidelines

The Guidelines will be widely distributed as well as made accessible online and upon request. It is intended that that as a result of publishing the Guidelines, wind-diesel developers and users will be able to use this document as a best practice reference point during their assessment. Adherence is voluntary, however, ACEP and WiDAC urge all responsible proponents to use the Guidelines as a benchmark to judge whether or not a project is appropriate, and also assess the degree to which a developer's approach follows the spirit and principles set down in the Guidelines.

While it is anticipated that individual circumstances can arise in which it would be unreasonable or over-prescriptive to insist on following certain best practices, the principle of the Guidelines in encouraging responsible, sustainable wind-diesel development should still be followed.

The Guidelines cover all scales of land-based wind-diesel projects but apply to different sizes of development in different ways, in cognizance of the fact that some wind energy developments are built as single one-off projects – possibly by a landowner – and others are built by specialist companies that may be looking to develop a number of sites.

[2] It is expected that the Guidelines will be maintained as a Wiki, managed by ACEP, and will be publicly available as a link from http://www.uaf.edu/acep/widac/wd-guidelines/ by January 2012.

1.2 Organization of the Guidelines

In developing the Guidelines, the phases of a W-D project from beginning to end are considered, based on the major steps in the development process:

- Planning
  - Site selection
  - Project feasibility (technical and economic, including financing)
  - Detailed assessment
  - Permitting
  - Power Purchase and Transmission Agreements
- Operations
  - Site development/construction
  - Power production management
  - Decommissioning.

Considerations for each phase of project development are broadly discussed, with recommendations offered for best practices intended to be directive where required or appropriate.

This Guidelines[3] handbook follows a chronological flow through the development process, structured into five Parts:

Part I explains the fundamentals of the wind-diesel technology, and consists of four Sections that explain classes of WD systems, anatomy of a WD project, technical aspects of WD facilities, and case studies of WD Systems in Alaska.
Part II recommends the best practices for project planning activities including: site selection, resource assessment, permitting practices, feasibility studies, environmental assessment, and WD design issues.
Part III offers various best practices and recommendations for:

- Site development, including foundation design in cold environments, and project commissioning;
- Site operations, including distribution system management, data management, and the decommissioning process; and
- Performance values for WD power systems.

The **Appendix** is a compendium of the step-by-step process necessary to obtain permits, approvals, and authorizations. Included is a set of regulatory agency consultations and pertinent contacts.

[3] **Self-guided tour** In addition to this handbook, there will be a comprehensive self-guided version available at the ACEP website.

PART I

FUNDAMENTALS OF W-D POWER SYSTEMS

2 Wind-Diesel Hybrid Systems in Alaska

Introduction

Several isolated off-grid electrification schemes consist of “hybrid power systems” – a terminology that describes two or more generating technologies that can incorporate different components and functions, including storage, production, power conditioning, and system control. This aptly describes the W-D power systems in remote communities in Alaska.

The classic wind-diesel hybrid system is based on a combination of fossil fuel engine generators and wind turbines, usually alongside ancillary equipment such as energy storage, power converters, and various control components, to generate electricity. Hybrid power systems are designed to increase capacity and reduce the cost and environmental impact of electrical generation at remote places and facilities that are not linked to the public power grid. If wind conditions are sufficient, W-D systems can lower the cost of electricity reducing reliance on diesel fuel for remote communities.

The successful integration of wind energy with diesel gen-sets relies on complex controls to ensure correct utilization of intermittent wind energy and controllable diesel generation to meet the demand of the usually variable load. The diesel gen-set regulates both voltage and frequency and provides the needed VAR support. One of the considerations with high-penetration wind-diesel systems is that, ultimately, the diesel needs to be shut off in order to realize maximum fuel savings. To supply the required power quality and balance the system’s total reactive power at all times without using diesel, other equipment is needed to provide VAR support, e.g., switchable capacitor bank, static converter, or synchronous condenser. This function can also be accomplished through power electronics such as inverters.

Chapter Contents

2.1 Classes of W-D Systems

Classification of Renewable Penetration

Amount of energy from renewable sources dictates components to be used when incorporating renewable-based technologies into large power systems. This energy is determined by the levels of system complexity, characterized by the following classification and definitions of system penetration:

$$\text{Instantaneous Penetration} = \frac{\text{Wind Power Output (kW)}}{\text{Primary Electrical Load (kW)}}$$

and

$$\text{Average Penetration} = \frac{\text{Wind Turbine Energy Output (kWh)}}{\text{Primary Electrical Load (kWh)}}$$

The difference in these equations is in the units:

- Instantaneous penetration is in terms of power; thus, it is the ratio of how much power is being produced by the renewable resources at any specific instant.
- Average penetration is in terms of energy; it includes a time domain and is thus measured over days, months, or even years.

To conceptualize the idea of penetration, average penetration is in the domain of the economist and instantaneous penetration falls in the realm of the engineer.

Table 2.1 shows a three-level classification system based on penetration levels that separates systems along power and system control needs.

Table 2.1: Penetration class of wind-diesel systems[1].

Penetration Class	Operating Characteristics	Penetration, %	
		Peak Instantaneous	Annual Average
Low	• Diesel(s) run full-time • Wind power reduces net load on diesel • All wind energy goes to primary load • No supervisory control system	< 50	< 20
Medium	• Diesel(s) run full-time • At high wind-power levels, secondary loads dispatched to ensure sufficient diesel loading or wind generation are curtailed • Requires relatively simple control system	50–100	20–50
High	• Diesel(s) may be shut down during high wind • Auxiliary components required to regulate frequency and voltage • Requires sophisticated control system	100–400	50–150

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[1] This classification was suggested by Steve Drouilhet, in publications with the NREL.

Low Penetration Systems

The wind energy contribution to the power system is rather limited, with instantaneous penetrations likely to be below 50%. In many ways, the energy generated by the wind turbines is seen as a negative load on the diesel plant. Wind power production is always less than the load and other power plants are constantly online to control frequency and voltage (if grid-connected). The control technology required at this level of generation is trivial; no form of automated control is required – the wind turbines, diesel gen-sets and possibly other components act under their commercial controllers and an operator monitors all system functions.

Medium Penetration Systems

This category of system is characterized by a larger ratio of renewable energy contribution that requires auxiliary components and an advanced supervisory controller to ensure that power quality is maintained. Some modifications to diesel controls may be necessary, as automated diesel operation is desirable. It is normal practice to integrate secondary loads, such as a resistance heater, to regulate system frequency. Several system configurations exist to ensure that the power system's high power quality is maintained, even with half, up to 100%, of instantaneous peak power being provided by intermittent renewable sources.

High Penetration Systems

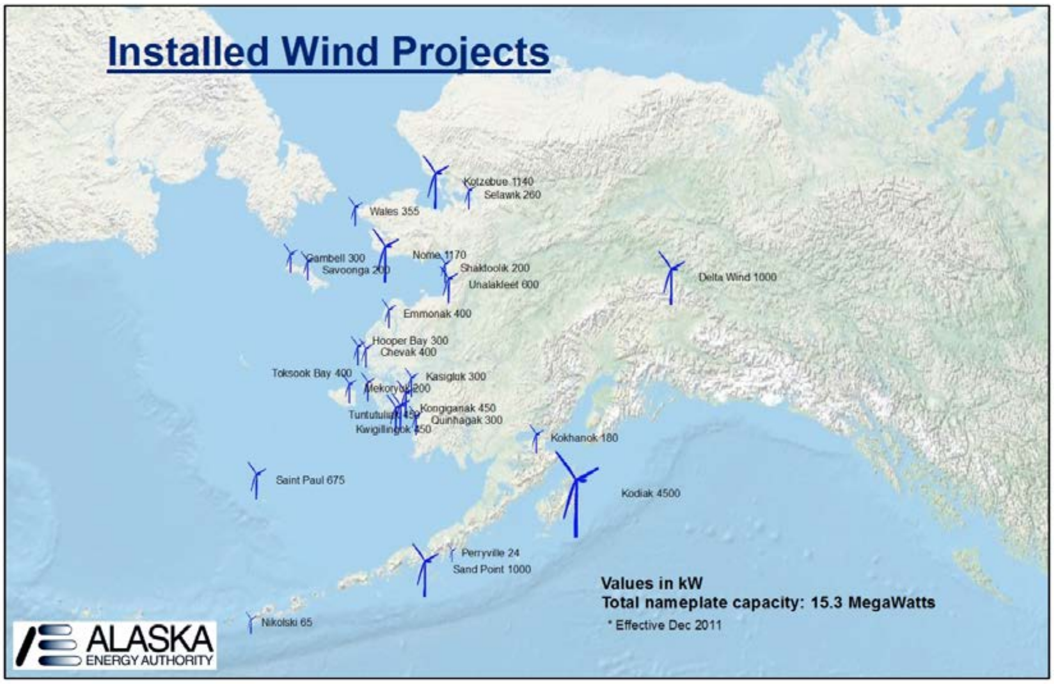
As instantaneous wind power penetration continues to rise, the potential exists to have more wind energy than is needed to meet community load. The ability of the gen-sets to control frequency and voltage is then significantly reduced. Unless there is a large need for additional energy, it is economical to shut off the diesel engines when the whole load can be supplied by renewable sources. They require a completely integrated power system with an advanced supervisory controller. Power quality and system integrity are ensured via components such as: converters, advanced system controls, load banks and dispatchable loads, and (possibly) energy storage.

Spinning reserve is created through the use of short-term storage or by maintaining a consistent oversupply of renewable energy. Potential fuel savings of up to 70% likely. Although this technology has been demonstrated on a commercial basis, high-penetration wind-diesel power stations require a much higher level of system integration, technology complexity, and advanced control.

2.2 Successful W-D Systems in Alaska

Background

Fig. 2.2. Installed wind capacity: Alaska utilities (Source: AEA)



Alaska's first utility wind farm was installed in 1997, when three Entegrity (formerly Atlantic Orient Corporation or AOC) turbines were erected in Kotzebue. In the next six years, the Kotzebue farm increased its capacity from 195 kW to 1.14 MW. Kotzebue was the proving ground for many of the technological challenges that Alaskans would face as additional wind turbines were erected over the next ten years. Since that first installation, significant development and innovations have occurred.

As of fall 2011, 27 wind projects had been completed in various communities around the state with a total installed capacity of 15.3 MW. Initial funding for Kotzebue and Wales came from the USDOE, which funds research but does not subsidize utility operations. Beginning in 2004, the Denali Commission funded projects in five communities (Selawik, Hooper Bay, Kasigluk, Savoonga, and Toksook Bay). In 2008, the Alaska State Legislature created the Renewable Energy Fund, a competitive program established to invest in renewable energy. Wind projects have received a substantial portion of the funds available through this program, which AEA administers.

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The incorporation of wind energy, which is abundant in Alaska, has moved from the initial demonstration phase toward a technology being considered for many community energy systems.

AVEC has committed to making new diesel power plants “wind ready” by designing electrical systems so that wind turbines can be incorporated in the future—which is indicative of the trend toward incorporating wind in more remote rural systems.

Alaska W-D systems are composed of a wide variety of configurations, components, and design factors and project developers must choose between them including:

- Secondary dispatchable loads (with associated secondary load controllers);
- Use of various types of energy storage;
- Ability to implement diesel-off operation;
- Small wind turbines or large wind turbines;
- Synchronous condensers;
- Power electronic converters; and
- Supervisory or distributed control system.

There are some basic trends which can be noticed over the course of development in Alaska. There is a general movement away from smaller turbines such as the Entegrity 65 kW and 50 kW Vestas toward slightly larger turbines such as the 100 kW Northern Power Northwind100 and 225 kW Vestas V-27. Most new systems, such as Kokhanok and Unalakleet, are focusing on addressing the community’s need for space and water heating. It is common practice to now have a fully automated diesel powerhouse prior to, or in parallel with, wind turbine installation. Also, to be fully optimized, a wind-diesel system must have appropriately sized diesel generator sets, to avoid running at an inefficiently low load when wind energy is being incorporated.

Table 2.1. Wind projects in Alaska (as of December 2011).

Location	Installer or Utility	Year Installed	Installed Capacity (kW)	Type of Turbines
Kotzebue	Kotzebue Electric	1997	1140	15x Entegrity; 1x Vestas; 1x Northwind
St Paul Island	TDX Power	1998	675	3x Vestas V-27
Wales	AVEC, KEA	2002	130	2x Entegrity
Kasigluk	AVEC	2006	300	3x Northwind 100
Nome	Bering Straits Native Corp	2008	1170	18x Entegrity
Delta	AEP	2008	1000	1x Northwind 100; 1x EWT 900
Perryville	Native Village of Perryville	2008	24	10x Skystream 3.7
Chevak	AVEC	2009	400	4x Northwind 100
Gambell	AVEC	2009	300	3x Northwind 100
Healy	AEP	2008	12	5x Skystream 3.7
Hooper Bay	AVEC	2009	300	3x Northwind 100
Kodiak	Kodiak Electric	2009	4500	3x GE 1.5
Selawik	AVEC	2003	260	2x Northwind 100
Mekoryuk	AVEC	2009	200	2x Northwind 100
Tin City	Tin City LRRS	2008	225	1x Vestas V-27
Toksook Bay	AVEC	2010	400	4x Northwind 100
Savoonga	AVEC	2009	200	2x Northwind 100
Unalakleet	UVEC	2009	600	6x Northwind 100
Nikolski	Umnak Power	2010	65	1x Vestas V-17
Chevak	AVEC	2010	400	4x Northwind 100
Quinhagak	AVEC	2010	300	3x Northwind 100
Sand Point	Aleutian Wind Energy	2011	1000	2x Vestas V-39
Kwigillingok	Kwigilingok Utility	2011	450	5x Windmatic 17S
Kongiganak	Puvurnaq	2011	450	5x Windmatic 17S
Tuntutuliak	Tuntutuliak	2011	450	5x Windmatic 17S
Shaktoolik	AVEC	2011	200	2x Northwind 100
Kokhanok	Marsh Creek	2011	20	2x Bergey

Unalakleet Case Study

Overview

Unalakleet is located 148 miles southeast of Nome. The Unalakleet Valley Electric Cooperative (UVEC) installed six 100 kW Northwind100 wind turbines which were completed in November 2009. UVEC provides services for 750 residents and businesses and is managed by Ike Towark and a seven member board. It is the single largest installation of Northwind100 turbines. It was one of the first wind projects implemented as part of the Renewable Energy Fund which provided $4 million in funding. The project, built over a four month period in the summer of 2009, cost $8.99 million[2] and the expected payback is 10 years at 2009 fuel prices[3]. It was also funded by the Norton Sound Economic Development Corporation (NSEDC) and the Unalakleet Native Corporation (UNC).

The development is projected to deliver 1,500,000 kWh of wind generated electricity[4], and produces enough electricity to power 86 homes for a year. STG, who installed roughly 75% of utility scale wind projects in the state of Alaska, served as Project Manager and General Contractor. Unalakleet experienced brownouts and voltage drops throughout commissioning, in part because the operators were not initially familiar with integration of wind. Cold climate modifications were made to the turbines including the use of alloys and metals that can withstand the harsh cold climate. The blades are also painted black with a special coating to deter frost build-up.

System Description

- (6) 100 kW Northwind100s, 161 foot towers;
- Northern Power System's Secondary load controller;
- Boiler provides heat to the school gym and offices.

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[2] http://www.ruralite.org/archive/2009/11/AK%20News%20pp%2025%20Nov_CMYK_Nov_2009.pdf
[3] http://www.alaskadispatch.com/article/small-wind-farm-pays-big
[4] http://www.akbizmag.com/alaska-news/2255-unalakleet-valley-electric-cooperative-celebrates-community-wind-power-installation-launches-project-web-portal.html

Challenges

- The power plant was upgraded 9 months after turbine installation; the wind turbines were not producing much at first, necessitating energy dumping until the new diesels and the SLC came online.
- High air density from cold air caused high power production due to the turbines overspeeding. The rotor needed to be governed. There was no active power compensation until newer software was installed on the encoder board (upgraded remotely through Smartview).
- Northern found it difficult to react and adjust as they had no data.
- The distribution line is very long and was undersized. Northern adjusted the PF on the turbines which worked to a degree. Northern eventually altered the transformer to reduce the drop[5].

Cold Climate Modifications

Alloys and Metals are used to build the turbines to withstand the harsh cold climate. Blades are painted black with a special coating to deter bug build-up.

Online Interface

The wind project offered the first web portal in Alaska to provide publicly accessible real-time energy production data and is intended to support educational efforts.

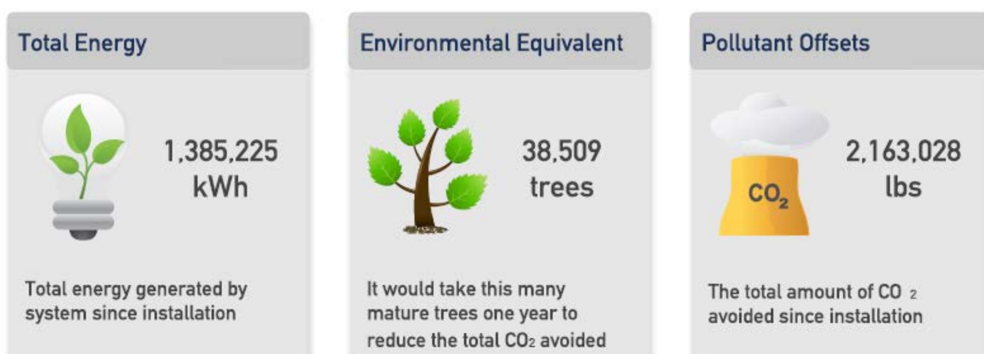


Figure 2.3: Performance since November 2009 (as of August 24, 2011).

[5] Personal Communication. Greg Price, Northern Power Systems. August 21, 2001

Kokhanok Case study

Figure 2.4: Wind turbines at the Kokhanok project.

Overview

Kokhanok is located at the southern tip of Lake Iliamna and has a tribally owned utility serving 200 people. Due to low river conditions that occur sometimes on the Kvichak River, Kokhanok must fly fuel at incredibly high costs. In 2009 the Village Council and the Lake and Pen Borough committed to developing their Class 6 wind resource. The Borough proceeded to issue an RFP for the design and development of a high-penetration hybrid wind project which included thermal energy production. Marsh Creek was awarded the engineering, design, and development in July 11th, 2009. Construction began in May 2010 and was completed on time and on budget on October 2010. In December 2010 system testing began. The project cost $1.94 million. The system is expected to save 19,300 gallons of fuel per year which equates to $110,000 per year in fuel costs. This is in addition to 8,886 gallons of further fuel savings at the school complex. This project was awarded the "Most Innovative Project" at the 2011 International Wind-Diesel Workshop in Girdwood, Alaska. Marsh Creek has also included a five-year maintenance and training agreement with the village to ensure that there is long term support for the cutting edge project.

Continued On Next Page

System Description

Kokhanok pursued a number of avenues before investigating the possible installation of a renewable energy system. First, they installed pre-pay “ampy” electric meters and contracted out their utility management to Marsh Creek. They then increased the efficiency of their diesel plant and balanced their distribution system. After the other items were complete they decided to integrate wind energy into their diesel plant after being stuck with $7.20/gallon fuel in 2008 (which equated to $.90/kWh). Excess electricity from the wind project is distributed to battery banks and a boiler that feeds into the existing jacket water heat recovery system and into the school’s recirculation system. The system is designed to operate in diesel-off mode when sufficient wind energy is available.

System Characteristics and Components

- Two 90 kW Vestas V17 turbines with 85 foot lattice towers. They were remanufactured by Halus Power systems in 2010;
- Diesel gen-set capacity of 495 kW (John Deere: 60 kW, 115 kW, 160 kW, 160 kW);
- Peak electrical load 110 kW;
- Synchronous condenser (249 kVAR);
- Grid forming inverter (200 kVA);
- Battery storage (336 kWh nominal);
- Advanced supervisory controller;
- Electric boiler and secondary load controller (240 kVA).

Challenges

- Commissioning delays due to long development of new equipment.
- Complex logistics and seasonal impacts on construction

Demonstrated Best Practices

- Pre-pay “ampy” electric meters
- Efficiency of their diesel plant and balanced their distribution system
- Five-year maintenance and training agreement with the village.

3 Anatomy of a Wind-Diesel Project

Introduction

Several isolated off-grid electrification schemes consist of “hybrid power systems” – a terminology that describes two or more generating technologies that can incorporate different components and functions, including storage, production, power conditioning, and system control. This aptly describes the W-D power systems in remote communities in Alaska.

The classic W-D hybrid system is based on a combination of fossil fuel engine generators and wind turbines, usually alongside ancillary equipment such as energy storage, power converters, and various control components, to generate electricity. Hybrid power systems are designed to increase capacity and reduce the cost and environmental impact of electrical generation at remote places and facilities that are not linked to the public power grid. If wind conditions are sufficient, W-D systems can lower the cost of electricity by reducing reliance on diesel fuel for remote communities.

The successful integration of wind energy with diesel gen-sets relies on complex controls to ensure correct utilization of intermittent wind energy and controllable diesel generation to meet the demand of the usually variable load. The diesel gen-set regulates both voltage and frequency and provides the needed VAR support. One of the considerations with high-penetration wind-diesel systems is that, ultimately, the diesel needs to be shut off in order to realize maximum fuel savings. To supply the required power quality and balance the system’s total reactive power at all times without using diesel, other equipment is needed to provide VAR support, e.g., switchable capacitor bank, static converter, or synchronous condenser. This function can also be accomplished through power electronics such as inverters.

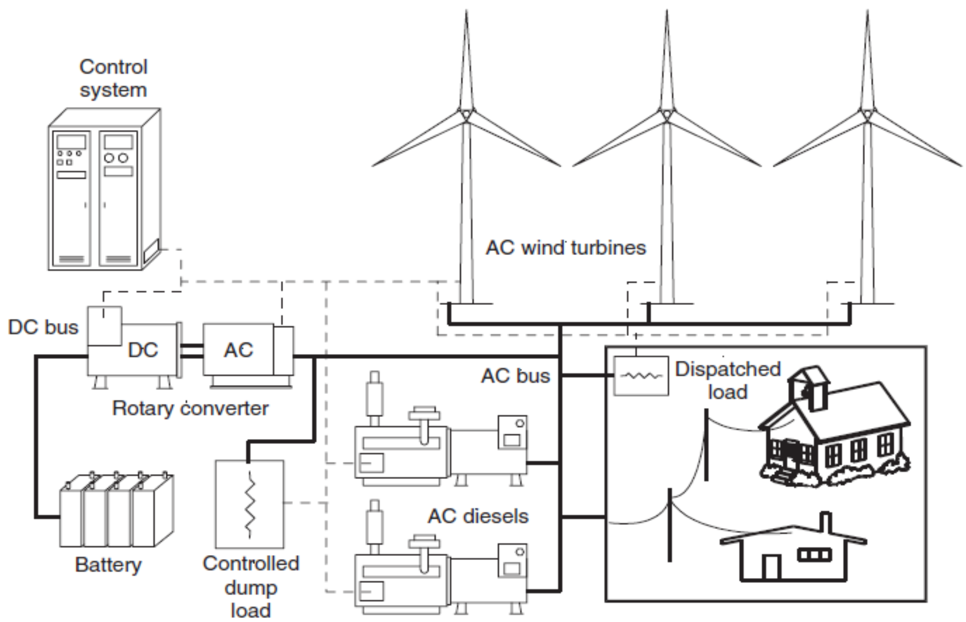
Chapter Contents

3.1 The World of Off-Grid Electrification

W-D Hybrid Power Systems

There are two general methods of supplying energy to remote Alaska communities: grid extension and the use of diesel generators. Both options can be exceedingly expensive, grid electrification costing upwards of US$3000 per connection[1], or a continued reliance on expensive and volatile diesel fuel. The inclusion of renewable technologies, notably wind, can lower the lifecycle cost of providing power. However, the wind resource is not dispatchable, and the technology needs to be combined with a more expensive dispatchable technology to provide the most germane alternative.

Fig. 3.14 A typical large wind–diesel power system[2]



The typical W-D hybrid system incorporates wind turbine(s), diesel engine(s), a battery bank, and a power converter. In most cases, this system is based on a two-bus system: a DC bus for the battery bank and an AC bus for the engine generator and distribution. The wind power technology may be attached to either the AC or DC bus depending on the system size and configuration. These systems usually supply AC power, although some loads may be tapped off the DC-bus bar.

[1] P. Lundsager and E. I. Baring-Gould, Chapter 14: "Isolated Systems with Wind Power," *Wind Power in Power Systems*, John Wiley & Sons, 2005.
[2] Ibid.

Scale of W-D Systems

A technically effective W-D system supplies firm power, using wind power to reduce fuel consumption while maintaining acceptable power quality.
In order to be economically viable, the investment in the extra equipment that is needed to incorporate wind power, including the wind turbines themselves, must be recouped by the value of the fuel savings and other benefits.

The general configuration for a W-D system as depicted in Fig. 3.1 can have a great deal of internal variability, leading to either a small- or large-scale system.

Smaller Scale Systems

These systems will likely use large battery banks, providing up to a few days of storage to cover the average load, and will use smaller renewable generation devices connected to the DC bus. These systems focus around the DC-bus bar, with the production of AC power coming from a power converter or diesel engines.
The battery bank acts as a large power dampener, smoothing out any short- or long-term power fluctuations.

Large Scale Systems

These focus the AC-bus bar, with all renewable technology designed to be connected to the AC distribution network. The battery bank (if used at all) is generally small and mainly used to cover fluctuations in power production. The systems usually contain more and larger equipment that allow for an economy of scale.
For equipment connected to the AC grid, the key issues are the balancing of power production and load and voltage regulation on a sub-cycle time scale. This is largely done with the use of synchronous condensers (rotary converters), dispatchable load banks, short-term storage, power electronics, and advanced control systems that carefully monitor the operating conditions of each component to insure that the result is power with a consistent frequency and voltage.

Control and Operation

W-D power systems can vary from simple designs in which wind turbines are connected directly to the diesel grid with a minimum of additional features, to more complex systems. The important complication of adding wind power to diesel plants is that the production of energy from the wind turbines is controlled by the wind, meaning most turbines cannot control either line frequency or voltage and must rely on other equipment to do so.

With only small amounts of wind energy the diesel engines can provide this control function, but with larger amounts of wind energy other equipment is necessary. Two overlapping issues strongly influence system design and its required components:

- System penetration – the amount of energy that is expected from the renewable sources; and
- Ability of the power system to maintain a balance of power between generation and consumption (the primary use for energy storage).

As the ratio of the installed wind capacity to the system load increases, the required equipment needed to maintain a stable AC grid also increases, forcing an optimum amount of wind power in a given system. This optimum is defined by limits given by the level of technology used in the system, the complexity of the layout chosen, and the power quality required by the user.

The higher the wind penetration, the more energy that cannot be used by the electric loads is generated. Other than dissipating this surplus power in a dump load the power can be used to satisfy additional community loads; these loads may be categorized as:

- Optional loads – loads that will be met only if and when surplus power is available as other energy sources can be used when excess energy is not available (e.g. space heating);
- Deferrable loads – loads that must be met over a fixed period of time, for example on a daily basis, and if not supplied by surplus power will be served by primary bus bar power.

Additionally, some loads can be controlled by the power system instantaneously to reduce the required power demand, thus saving the system from having to start an additional generator to cover what is only a momentary shortage of power.
This is often referred to as *Demand-Side Management.*

4 Technical Considerations for W-D Facilities

Introduction

Wind-Diesel Hybrid Systems

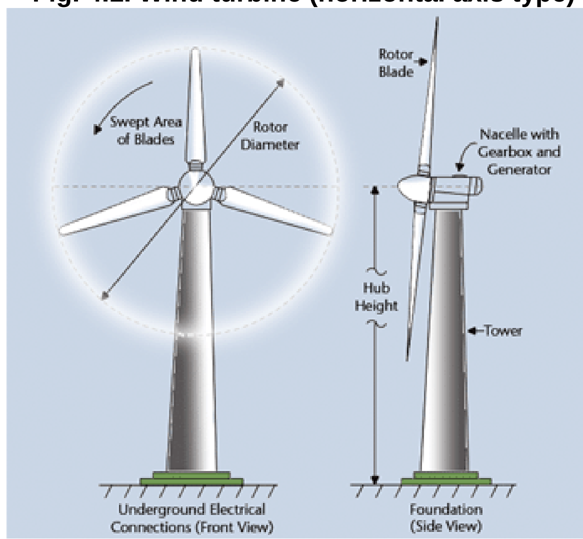
Renewable energy technologies use, and are at the same time limited by, the various forces of nature to produce energy. In particular, the wind does not always blow, requiring wind turbine systems to combine with fossil fuel generation systems. Combining renewable technologies generally increases the reliability and often the efficiency of energy production. This combined use of renewable energy technologies is described as a hybrid. Each technology is capable of complementing or circumventing the gaps in power generation, physical limitations or economic efficiencies of the various technologies. Hybrid systems are used whenever large amounts of reliable energy are needed at all times. They are more costly and complex, but make up for this disadvantage by their reliability.

Chapter Contents

4.1 The Wind Turbine System

Wind Turbine Basics

Fig. 4.1. Wind turbine (horizontal axis type)



Wind turbines are structures that produce power by capturing the kinetic energy in surface winds created by the sun and converting it into energy in the form of electricity. A wind turbine consists of six major components:

1. A rotor that aerodynamically converts the wind energy into mechanical energy on a slowly turning shaft;
2. A gearbox that increases the rotor-shaft speed for the generator. Some specially designed generators do not need a gearbox;
3. A generator that produces electricity;
4. A control and protection system that optimizes performance and keeps the machinery operating within safe limits;
5. A tower that raises the rotor high off the ground where the wind speed is greater and the effects of local obstructions are less; and
6. A foundation that supports the wind turbine system, sometimes with the aid of guy wires.

The electricity generated is carried by cables to distribution or transmission lines that connect to the larger electrical grid in the case of large turbines, or to homes or business operations in the case of small turbines.
Key factors that affect the power produced by wind turbines are:

- the strength of the wind;
- the area swept by the rotor; and
- the height of the turbine.

Continued On Next Page

Large versus Small Turbines
Wind turbines can be divided into five groups with respect to the range of the nominal power as listed in Table 3.1 (power limits are approximate and should be seen as a guideline only).

Table 4.1. Categorization of wind turbines.

Nominal Power (kW)	Typical Application
< 1	Micro systems
1-–10	Domestic/home wind
10–-200	Hybrid/Isolated systems
200–-1000	Grid connected – single or in cluster
> 1000	Wind farms (Offshore/onshore)

There are vast differences between large scale turbines that can be grouped into wind farms and operated as an energy generation enterprise, and small scale wind turbines that might sit on a farm or residential property and cover the electricity needs of the owner.

Many other sources also differentiate between different sizes of small scale turbines, referring for example, to mini, micro, small and medium as various categories. There is no consensus on the thresholds for defining these various categories. For the purposes of this report, the definitions of large and small wind turbines are based on the intended use of the power produced, following roughly the following size guidelines:

- Large scale turbines will be considered those that are commercially operated and 300 kW capacity or higher; These generally produce electricity to be fed directly into the power grid.
- Small scale turbines will be considered those owned and operated for the owner's use and typically having a capacity of less than 300 kW.

There are also vast differences in how the wind energy industry defines small and large scale wind turbines. Examples of these differing definitions are:

- Based on nameplate rated capacity;
- Based on the total turbine tower height (e.g., <60 m is small scale);
- Based on the rotor diameter and total swept area (rotor diameter of no more than 15 m and a total swept area of no more than 180 m^2 for small turbines);
- Based on the intended end use of the power produced (small scale is primarily for on-site consumption and large scale is generally intended to feed electricity into the provincial grid); and
- A combination of the above.

Selection & State-of-the-Art Components

The present “state-of-the-art” large wind turbine is a 3 bladed upstream machine with tubular tower using:

- Active stall with a two speed asynchronous generator, or
- Pitch control combined with variable speed, mainly realized using the configuration that includes a doubly fed induction generator with a rotor connected IGBT based frequency converter);
- Some manufacturers have started building gearless (variable speed) wind turbines.

Selection of wind turbines for installation at a particular site will depend on many factors including cost, load demand, W-D system configuration, and the important technical characteristics of the wind turbine types currently available. The dominant wind turbine configurations that are important for the purposes of this Guidelines are as follows.

I. Fixed-speed wind turbine
Rotates at almost constant speed, because the generator is directly connected to the fixed frequency electricity network.

- Pitch-regulated – the blades can be rotated about their longitudinal axis to control the aerodynamic torque, output power and for braking.
- Stall-regulated – the blades are fixed at an angle such that in high winds aerodynamic stall occurs, limiting the power generated.
- Active stall – similar to stall regulation, but the blades can be rotated, slowly and over a small angular range, so that the same power/wind-speed characteristic can be maintained irrespective of air density and blade fouling. Active stall may be used like pitch control (Siemens).

II. Variable-speed wind turbine
Rotates at a higher speed in higher winds, so that the rotor operates close to peak aerodynamic efficiency over most of the operating range. Variable-speed operation is achieved by providing a power electronic converter to connect the variable-frequency output of the generator to the fixed-frequency electricity network. This converter can also provide control of power factor.

- Pitch regulated – for control of blade angle to limit power conversion
- Direct drive – has a low-speed generator directly connected to the wind turbine rotor, removing the need for a speed-increasing gearbox. In this case all the output power flows through the power converter.
- Doubly-fed induction generator (DFIG) – stator directly connected to the fixed grid frequency. The rotor circuit is connected via a power converter, which therefore only has to handle about 30% of the output power, and is correspondingly smaller, cheaper and more efficient.

4.2 Diesel Generation

Status of Diesel Generation

What is Diesel Generation?
Diesel generators are run by internal combustion engines that operate by the injection of fine diesel fuel droplets into a combustion chamber heated by compression (“compression-ignited”, or CI). The air heats the fuel and causes it to evaporate and mix with the available oxygen. The fuel ignites and spreads through the chamber. Power output is managed by controlling the amount of fuel injected into the combustion chamber.

Alaska Village Power Market Setting
The diesel industry has an extensive business network in Alaska, since diesel generators were the original power technology of choice to light up the state’s remote villages. The industry includes distributors and servicers located in all major Alaskan cities, who can reach a remote village in need in one or two plane flights. Some distributors and servicers are owned by large diesel generator manufacturers. Overall, the industry is stable but highly competitive for village bids.
W-D power systems show strong promise for the Alaskan remote village power market, where diesel generators serve as “baseload” generation within small community power grids. However, the wind-diesel industry is relatively immature, with very little in-state presence, a high reliance on custom products, and no favorable subsidy treatment from state and federal agencies. The first wind-diesel hybrids in Alaska were made possible through strong government involvement in project formulation, design and funding, though primarily for demonstration purposes. It is recommended that

1. Diesel equipment firms should diversify by retrofitting diesel generators with wind power.
2. State (and federal) governments should tailor financing to wind power rather than diesel power.
3. There should be an active focus by the state/federal government and the wind industry to train local citizens to install and maintain wind-diesel systems.

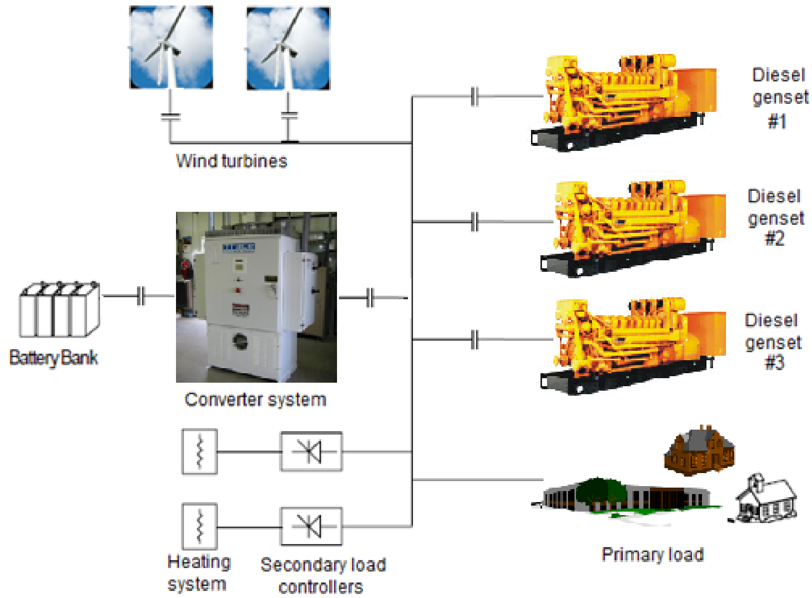
The main issues for consideration with regard to the relation between the W-D project and the environment are:

- Exhaust Gas Emissions: NOx, SO_2, and particulate matter
- Global warning effects from CO_2
- Noise emission
- Risk of fuel spills
- Disposal of used lubrication oil.

4.3 Storage Options for W-D Systems

Storage or No Storage?

Fig. 4.2 Concept of a W-D system with storage primed for diesel-off operation.



All high-penetration systems, with and without storage, have been installed in northern climates where the extra energy can be used for heating buildings or water, displacing other fuels. In these systems, it may be wise to install uninterruptible power supplies (UPSs) on critical loads. Although few systems have been installed, the concept is economically attractive and can drastically reduce fuel consumption in remote communities.

In systems incorporating storage, the storage is used to cover short-term fluctuations in wind power. The premise of this system design is that a large penetration of wind is used (up to 300% of the average power requirements), and when the renewable-based generators are supplying more power than is needed by the load, the engine generators can be shut down

During lulls in the renewable power generation, discharging the battery bank or other storage device supplies any needed power. If the lulls are prolonged or the storage becomes discharged, an engine generator is started and takes over supplying the load. Studies have indicated that most lulls in power from the wind are of limited duration, and using storage to cover these short time periods can lead to significant reductions in the consumption of fuel, generator operational hours, and reduced generator starts.

PART II

RECOMMENDED BEST PRACTICES FOR

PROJECT PLANNING
AND
INTEGRATED RESOURCE ASSESSMENT

5 Site Selection and Resource Assessment

Introduction

Several wind-diesel projects are at various stages of implementation (from planning to commission/operation) in Alaska, and it is important to realize that wind power cannot completely replace conventional power MW for MW. Getting the correct balance requires refined and constantly improved modeling of wind energy in Alaska over all timeframes.

In many areas in Alaska, small wind turbines are being combined with diesel generators in order to form more reliable hybrid systems. However, wind presents a major challenge when modeled as a production resource: it is variable in amplitude over a wide range of timescales. Nonetheless, its statistical properties are understood and it is predictable to some extent on some timescales. As wind penetration grows it is imperative that appropriate modeling techniques for wind energy are utilized so that the generation adequacy of the power system as a whole does not degrade.

In developing wind-diesel power projects, the developer should seek to balance the need to protect residents and their communities from social and environmental impacts, the need for flexibility from the industry, and the general desire to increase renewable energy integration. The Guidelines provide context as to how to approach various issues in consideration of the unique characteristics of Alaska – its communities, governance structure, land use patterns, geography and topography, wind potential, and commitment to renewable energy alternatives.

Chapter Contents

The table below lists sections included in this chapter.

5.1 Site Selection and Project Planning

Site Finding and Suitability Assessment

For Alaska, the development of a wind-diesel power project is typically initiated by a land owner, a developer or the proactive planning of a local community. In each case the process starts with finding a site that is suitable for wind power development. The planning and design of the wind-diesel project is a compromise between high energy yield, easy access, easy permitting and commercial viability. Careful consideration of a very large number of factors is typically required to reach the best designs and consequently dedicated software tools are used by the majority of developers.

At the most basic level, after establishing that the output from a wind power project can be sold at an acceptable price, the following are the acid tests for any potential development:

1. **Land availability** – can the rights to the land be secured? Land ownership/land uses are determining factors (federal special use permits, state leases, rights-of-way access, etc).
2. **Grid connection** – is proximity to a medium voltage grid likely to be cost effective for the desired size of development? Cost for high voltage grid connection may be prohibitive.
3. **Wind resource** – is the wind resource adequate? Good exposure, particularly in the prevailing wind direction, will substantially improve the resource at a site.
4. **Building permits** – will the project be able to obtain all the permits necessary for the wind-diesel project to be built?
5. **Access** – is access to the site and construction of the wind farm likely to be cost effective? The distance to the nearest road access and the complexity of the terrain will substantially influence the capital cost of the project.

A good expectation that the answer to all of the above tests will be positive is a pre-requisite for making the investment necessary to realize a project, although inevitably early decisions need to be made on incomplete information.

Initial Planning Activity

The initial planning process identifies suitable locations for wind energy development based on an evaluation of a number of statutory factors that present technical, commercial or environmental constraints as presented above: *land availability, grid connection, wind resource, permitting,* and *accessibility*.

Planning and site selection typically involve carrying out initial studies of the possible technical, environment, statutory planning and community aspects, carried out in accordance with the various federal and state planning and environmental laws that govern wind energy developments.
Table 5.1 summarizes the main considerations in site selection.

Table 5.1 Site considerations

	Consideration/Assessment	Technical	Environmental	Consultation
1	Wind Resource	■		
2	Land – landownership, land availability • Existing (current, previous and future use) land usage patterns at site; • Existing commercial uses e.g., agriculture, recreational activities, etc. • Potential for reasonable size of generation facility.	■		
3	Ground conditions – permafrost considerations	■		
4	Electrical infrastructure – cost-effective electric connection access	■		
5	Site access, ease of construction.	■		
6	Draft project design – proponent's analysis of project's economic viability	■		
7	Visual resources and landscape assessment		■	
8	Noise assessment, as per state and local standards		■	
9	Ecological assessment – wildlife, vegetation and critical habitat, including sensitive and/or protected & conservation areas, and biological wealth/endangered species		■	
10	Hydrological assessment – Surface waters, drinking water supplies		■	
11	Geotechnical instability	■	■	
12	Historical heritage, cultural, and archeological resources		■	
13	Fire risks		■	
14	Telecommunications/Electromagnetic interference		■	
15	Civil and military airports/Aircraft safety/Aviation and defense radar resources		■	
16	Safety assessment – community and residential area issues, schools, hospitals, etc		■	
17	Traffic management and construction		■	
18	Effects on the local economy		■	
19	Tourism and recreational effects – trails, scenic sites, recreational areas		■	
20	Decommissioning	■	■	
21	Restricted areas/military land		■	■
22	Landowners, local planning authority/and statutory stakeholders			■
23	Local communities			■

I. Initial Technical and Commercial Considerations

Extensive studies should be performed covering wind resource, site capacity, accessibility, and electrical connections. Statutory factors to consider include:

- The potential for beneficial uses of waste energy from the project;
- The direct and indirect economic impacts of the proposed facility;
- Existing plans for other developments in the vicinity of the site.

Wind Resource

It should be established that there is adequate wind resource for operation of the facility for power production[1].

Infrastructure

The project needs to be strategically sited to take advantage of existing transmission capabilities or develop new electric transmission system infrastructure as needed for distribution of the renewable energy.

Accessibility

Logistics for getting diesel fuel to the wind-diesel project as well as storage should be considered – this is particularly an issue with most isolated communities in Alaska where it is difficult and expensive to transport fuel.

Land

The purpose of wind energy option, easement, and lease agreements is to allow the developer to test the land for feasibility of a wind energy development, to allow for construction, operation, and transmission of electricity generated by the wind-diesel project. Generally

- There should be adequate land for the construction of the project;
- Requirements and/or limitations set by nearby installations should be adequately addressed;
- Ground conditions at the site should be examined to guarantee construction of turbines, the erection of the machines and the provision of access roads. In particular, permafrost in parts of Alaska may require additional consideration, and cost, for tower foundation.

Other key challenges that need to be planned for include ROWs, better mechanisms to incorporate land use and landscape values, compensation for option, easement, and lease rights (including amount, method, and duration), and possibly, the tax consequences to the landowner based upon the method of compensation.

[1] Cost effective, large-scale wind turbines require an annual average wind speed of 13 mph (5.8 m/s) at 10 meters height, while small wind turbines require only 9 mph (4 m/s).

II. Initial Environmental Considerations and Social Impacts

Environmental Aspects
Case studies of several wind projects that have been successfully developed in Alaska provide insight on how community concerns have been acceptably addressed. The list in Table 5.1 is representative of the common public concerns potential W-D developers should anticipate during the permitting process. An EIA is conducted with the initial analysis covering landscape classification, visual amenity, ecology, etc., to establish the effects on public health and welfare, natural resources, and the environment.

Social Impacts
It is vital for the developer to assess and communicate how the communities will benefit from efforts to install renewable energy developments by:

- Managing social outcomes – developer needs to include the resolution of differences between project goals and those of the local community
- Gaining community acceptance – this requires that issues of concern are identified and resolved in an open and transparent manner.

Wind-diesel projects can significantly contribute to employment in regional communities. Linked to this are investment attraction, infrastructure development and local tourism opportunities. These in turn benefit local industry, support the social fabric of communities and promote economic activity. With a reliable power supply, industry is encouraged and social capital increases.

III. Initial Consultation and Communicatior

Construction impacts during development and occasional communication problems between contractors, landowners, and other stakeholders as well as potential operational issues are major concerns with local communities surrounding sites earmarked for W-D projects. It is recommended that even in this initial site selection stage, a preliminary communication and consultation plan be developed to establish preliminary dialogue between developer and stakeholders, who may include the planning authority, local government, the local community, local interest groups and state government officials.

It is recommended that developers get the assistance of specialist consultants during the site selection stage, for peer review work undertaken in-house, and in some of the following disciplines: wind resource analysis, environmental profile assessment, geotechnical issues, cultural heritage, socio-economic, and project management and engineering.

5.2 Wind Resource Assessment

Best Practices in WRA Implementation

A comprehensive WRA is essential for the success of any W-D project. For small W-D projects (up to 500 kW) a met tower at the planned project site may be sufficient to conduct the WRA. Otherwise it is recommended that an estimation of the wind energy resource potential at a given site be conducted using suitable modeling techniques. The assessment of the wind resource and annual energy production requires some or all the following:

- Data (from published wind resource maps such as PNL's Wind Energy Resource Atlas of the USA, WMO, airports, met stations, etc)
- Existing wind turbine production statistics;
- Surrounding topography – 1:25000 maps, 5–10 mile distance;
- Assessment of existing wind data and new measurements at the site;
- Wind resource assessment tools (e.g., WAsP, WindMap, etc)
- Extreme winds (Gumbel distribution) and turbulence (from modeling software, and anemometer measurements);
- Candidate lay-out of wind turbines (co-ordinates of the turbines); and
- Turbine characteristics (power curve, hub height, rotor diameter, etc).

A WRA based on onsite wind measurements can provide not only the annual average wind speed, but also provide turbulence and extreme wind conditions – data that is necessary to select the class of wind turbine. Generally, some of the entities mentioned above do not have sufficient detail for rural Alaska – their data provides insight to the prevailing wind resource situation at the proposed project site, but are not a substitute met tower data.

Generation adequacy for a particular site is in part based on the class of the wind resource; wind is classified according to wind power classes, which are based on typical wind speeds: Class 1 (the lowest) to Class 7 (the highest).

Table 5.2. Classes of wind power density at 10 m and 50 m[2].

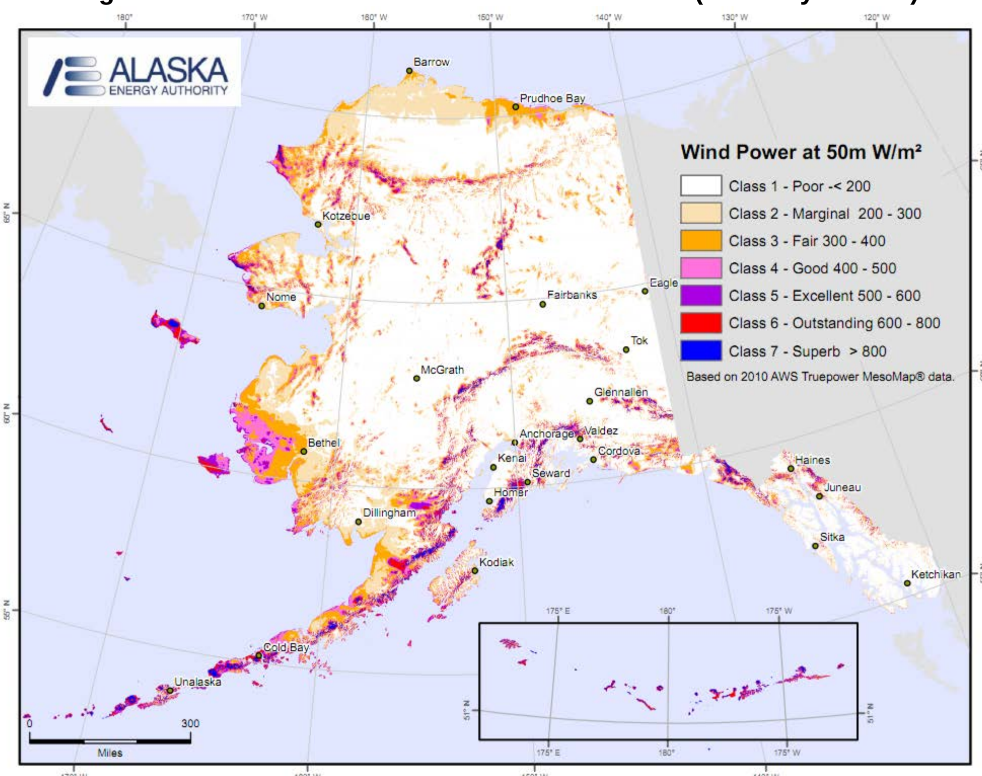
Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density (W/m^2)	Speed m/s (mph)	Wind Power Density (W/m^2)	Speed m/s (mph)
1	0	0	0	0
2	100	4.4 (9.8)	200	5.6 (12.5)
3	150	5.1 (11.5)	300	6.4 (14.3)
4	200	5.6 (12.5)	400	7.0 (15.7)
5	250	6.0 (13.4)	500	7.5 (16.8)
6	300	6.4 (14.3)	600	8.0 (17.9)
7	400	7.0 (15.7)	800	8.8 (19.7)
	1000	9.4 (21.1)	2000	11.9 (26.6)

[2] NREL, http://www.nrel.gov/rredc/wind_resource.html

Mesoscale Wind Modeling

The wind energy potential for a given site may be obtained via the Mesomap system that consists of numerical models, meteorological/geophysical databases, and computer processing and storage systems, for wind maps. Mesoscale wind mapping is based on data from earth observation satellites, historical reanalysis data, and global meteorology models, and is increasingly used to obtain a preliminary, crude mapping of likely locations for commercially exploitable wind resources without using ground based measurement data for anything but verification purposes.

Fig. 5.1. Potential wind resource sites for Alaska (courtesy of AEA).



Class 4 and above are considered good resources. Generally, at 50 meters, wind power Class 4 or higher can be useful for generating wind power with large turbines. A number of locations in the Class 3 areas of Alaska may be suitable for utility-scale wind development as they could potentially have higher class values above 50 m because of possible high wind shear. Site-specific wind resource and reliability is essential for planning a W-D project. Such data has been compiled for some areas of Alaska by NREL, AEA's anemometer loan program, and from airport weather stations managed by the NWS[3] or FAA (obtainable from the NCDC[4]).

[3] National Weather Service, http://www.weather.gov/
[4] National Climatic Data Center, http://www.ncdc.noaa.gov/oa/ncdc.html

Mast Installation and Specification of Anemometry

The wind resource at the site is the key parameter in determining its economic viability. To assess the energy for a WD project it is necessary to obtain data on the local wind regime. For wind monitoring and analysis, anemometer towers usually are the first structures built on a site to determine whether it has adequate wind resources for cost-effective development. Typical anemometry equipment comprise:

- The meteorological mast for mounting the wind measuring devices;
- Anemometers – these continuously measure wind speed and direction (wind turbines will begin operating when the anemometers detect sufficient wind speed); and
- Data logger – for recording data from the anemometers.

The instrumentation may include wind vane(s), and measurement of temperature and pressure, which requires additional sensors. During operation of the wind facility, permanent anemometers are used to transmit information about wind speed and direction to each wind turbine and to the control facility, where a record of wind speeds is stored.

Installation

Anemometers can be mounted on meteorological towers – typically tubular towers supported by guy wires, and may be temporary and moved around the potential site (or sites). When installing the wind measurement system, consideration should be given to met mast decommissioning procedures, which can be combined with met mast overhaul, refurbishment and installation at a new site.

Specifications

- As a general rule the mast should be at least two thirds of the hub height of the turbines;
- A useful rule in complex terrain is that no turbine is located more than 1 km from the closest mast. In very severe terrain, the closest mast should be within 500m, but for wind farms located in simple terrain a much lower density of masts over the site may be appropriate;
- For large developments that require several masts there may be advantages in initially installing just one mast on the site. Once it is confirmed that the wind resource is reasonable, other masts can be installed to confirm the variation in wind speed over the site area (the original mast remains as a constant reference; other masts can be moved or removed after, say, six months of operation to reduce the total number of masts required).

6 Project Feasibility

Introduction

The grid connection in W-D systems has to be evaluated in more detail than in stronger interconnected high voltage systems. The dynamic effects of the wind power integration on the electrical parameters of the small fragile isolated grid (such as frequency, reactive power and flicker) can become critical. Both technical and economic developments in time should be considered, and if the technical lifetime of the installed technology exceeds the economic life of the project, the salvage value of the equipment at the end of the economic life should be added to the income of the system. Some of the parameters to consider in the feasibility study include:

I. Technical

- Consumer demand in terms of primary and secondary load types
- Generating capacity in terms of e.g. active diesels and their replacements / extensions
- O&M needs as generating capacity ages and expands
- Operating strategy and priorities

II. Economic

- Consumer rates and tariffs
- Fuel costs and prices
- O&M costs as existing capacity ages and new capacity is added
- Major repairs / overhaul / retrofit

III. Financial

- Inflation
- Interest rates
- Taxes, duties and deductions

Ideally the development scenario should be represented by tables specifying the assumed values of the above parameters year by year during the entire project life. The technical-economic models used should be able to utilize this information in a life cycle cost analysis.

Chapter Contents

6.1 Technical Feasibility

Technical Performance

The technical performance will be assessed by applying a variety of measures that include overall system performance as well as performance of the individual components of the system. For prospective systems the determination of the performance figures will usually involve system simulations using a variety of models each capable of simulating specific aspects of the system behavior. This includes screening models, logistic (power flow) models, load flow models, dynamic models and transient models. In order to calculate the specified measures system operating strategies have to be specified and implemented in the relevant models.
It is also important to specify how the performance is verified on the system.

Performance Characteristics
By evaluation of the performance characteristics it is possible to compare the various scenarios at:

- System level – measures include security of supply, total fuel consumption, saved fuel as well as potential and utilized wind energy;
- Component level.

Table 6.1: Range of relevant performance characteristics.

Conventional Generation	Wind Energy	Storage	Power Quality & Grid Stability	Production Statistics
• Power production • Running hours • Fuel consumption • Fuel tank capacity requirements	• Potential production • Utilized production • Capacity factor	• Energy in/out • Efficiency • Life time consumption e.g. charge cycles	• Loss of load expectation/ probability • Loss of energy • Voltage quality • Frequency quality • Supply reliability	• Primary load • Optional load • Deferrable load • Penetration of wind energy • Dumped energy

The range of performance characteristics is very wide – some are calculated on a time scale of years and others at a time scale of sub seconds.
In the design and analysis phase of a project these numbers are calculated using simulation models. Separate models have to be applied due to the different time scales as well as the different nature of the measures.

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Technical Performance Verification

The use of the performance characteristics in Table 6.1 is twofold:

- They are used directly in the comparison between the scenarios studied; this includes characteristics such as loss of load probability, voltage quality and frequency quality.
- Some of the figures are used in the economic performance calculations; these are fuel consumption, utilized wind energy, and expected battery lifetime.

A major and very difficult task is to specify procedures for the verification of the performance of the W-D system. The main difficulty arises from the fact that the system performance specifications are often based on a complex set of assumptions made in the design phase due to a lack of data on the conditions in which the system will be operating.

One approach is to establish the actual operating conditions as accurately as possible together with measurements of the main system performance measures. The exercise is then to transform the observed system performance at the actual conditions to the conditions specified.
This can be done using the same models as applied in the design phase of the project. It is a difficult task and the results will often be open for interpretation.
It is recommended to simplify as much as possible the guaranteed performance data and state the proposed procedure for performance verification at an early stage in order to maintain a high level of confidence with the project stake holders.

System Modeling Requirements

Numerical modeling is an important part of the design, assessment, implementation and evaluation of isolated W-D power systems. Usually, the performance of such systems is predicted in terms of the technical performance (power and energy production) and the economic performance, typically the cost of energy (COE) and the internal rate of return (IRR) of the project. Technically, the performance measures may also include a more detailed design-based analysis of:

- Power quality measures;
- Load flow criteria;
- Grid stability issues; and
- Scheduling and dispatch of generating units (diesel gen-sets).

Modeling

The technical (and economic) performance of prospective W-D systems is analyzed by computer simulation, and several types of models are used depending on the characteristics on which the simulation is focused.
The main parameter characterizing the models is the time scale of the simulation, and the following types are normally distinguished:

- Screening models – give an overall assessment of the performance of the system, without considering detailed specifics in the operation of the system.
- Logistic models – these focus on predicting the annual power productions, fuel savings and power flows in the system. Logistic models are usually the basis in screening models, and they may be deterministic time series models or probabilistic models that produce probability distributions.
- Dispatch models – focus on the dispatch of the various power producing components of the system, i.e. start/stop of diesels etc. Time scale typically minutes to an hour.
- Dynamic models – focus on the electromechanical behavior of the system, i.e. machine dynamics (electrical switching is not represented). Typical time scale: a few seconds to half an hour.
- Transient models – focus on electrical transients including switching. Time scale typically seconds to minutes.

System control models focus on a representation of control strategies of the system, or parts of the system, based on Dispatch type models.
A number of numerical modeling techniques and models are available for the assessment of technical-economic performance wind-diesel systems. One such model is briefly described below:

HOMER

This is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation applications. HOMER's optimization and sensitivity analysis algorithms allow the user to evaluate the economic and technical feasibility of a large number of technology options and to account for uncertainty in technology costs, energy resource availability, and other variables. HOMER models both conventional and renewable energy technologies, including power sources, storage, and loads.

6.2 Economic Feasibility

Economic Performance

It is necessary to distinguish between economic and financial performance:

1. The analysis of economic performance excludes items such as local taxes and is used to provide the community's decision makers with a basis for comparing the investment in the proposed project with other options, not necessarily related to energy production;
2. Financial analysis results, where local taxes etc. are included, are used to provide the prospective developer and his financiers with a basis for a decision on whether the financial returns are satisfactory and thus warrant an investment in the project.

Wind power feasibility studies are almost always contracted out and will require anywhere from six months to two years to complete, depending on whether on-site wind data has already been collected. Some of the considerations in performing economic feasibility studies are:

- Establish that the project is economically feasible
- Show that the project has an adequate financing plan
- Examine the local cost of energy, and the comparative cost and economic benefits from an installed wind system.

Assessment of Results

The results of the economic/financial analyses come in the form of annual cash flows specifying the projected expenses and income from the installation and operation of the project. The economic/financial indicators used to assess the results include:

- Levelized production cost, LPC (cost/kWh) of wind energy
- Short run marginal cost, SRMC (cost/kWh) – with and without the assessed wind power plant
- Net present value, NPV of the project
- Economic internal rate of return, EIRR (% p.a.) of the project
- Financial internal rate of return FIRR (% p.a.) of the project
- Return on Equity ROE (% p.a.) for the investor
- Simple payback time (years) of the project
- Cost of alternative technologies (relevant for the case considered).

The results will be assessed by comparing the economic/financial indicators with the criteria / threshold values applied by the investor/financier/donor in question for the project.

Financing Mechanisms

The financing of new W-D projects is complicated by the different cost characteristics of each. Specifically, wind projects are capital-intensive to build but have no ongoing fuel costs, while fossil-fueled power projects are less capital-intensive (per unit of production) but have higher operating (e.g., fuel) costs. Furthermore, whereas federal tax incentives for fossil-fueled power plants can be (and generally are) distributed throughout the entire fuel cycle (e.g., from exploration and extraction to transportation, power production, and emissions controls), tax incentives for wind projects are instead targeted almost exclusively at the power production stage.

In structuring the W-D project for financing (i.e., allocating the risks and returns of a project among the various project participants), the developer may have a wide variety of instruments that can be used to finance the development. The following three categories characterize the major types:

1. *Equity* – High risk financing that expects high returns. An equity investment can be made in support of a specific project or equity funds can be provided to the company carrying out the project. Equity investors maintain the right to get involved in the decision making process of the project or company in order to protect their investment.

2. *Debt* – Medium risk with modest expected returns. In contrast to equity investors, lenders who provide debt financing to a project do not own shares in the project. They provide capital for the purpose of earning interest. Because lenders must be repaid before distributions can be made to shareholders, lenders bear less risk than equity holders. For this reason, potential return to lenders is limited to risk-adjusted market interest rates.

3. *Grants* – No expected returns. Federal, state agencies, or governmental organizations offer grants (donations) to promote environmental and developmental policies. Renewable energy projects are often eligible for these funds.

In most cases each of the above types of investment capital are usually combined to capitalize the initial investment.

Financial incentives and financing mechanisms that are provided by the public sector help stimulate private investment, and Alaska is one of the jurisdictions with aggressive and enforceable targets for renewable energy that can justify publicly-backed financial incentives for wind development.

7 Environmental Impact Assessment and Site-Related Constraints

Introduction

The siting process for a WD project should include steps to minimize both environmental and social impacts. This section outlines best practices that will help to maximize the effectiveness of this process. As a starting point, the following subjects should be investigated in the EIA inter alia:

- Description of the present energy situation for the general area;
- Description of location of the project site, characteristics of operational units, their size, capacity and other specifications (wind farm, diesel plant, transmission line);
- Description of the quantity and extent of the excavation activities for land preparation and special transportation of construction material;
- Investigation of all relevant federal, state, and local as well as international contracts considering the impact of the environment;
- Investigation of possible impacts of the project to the defined area, description of possible incidents, and precautions to be taken.

Chapter Contents

7.1 Comprehensive Environmental Assessment

EIA Planning Process

Environmental Impact Assessments (EIAs) are conducted to inform decision makers of positive and negative effects of a project and associated mitigation measures. W-D projects can have a number of environmental impacts that need to be identified early and avoided, mitigated, or compensated.

Crucial in this process is the effectiveness of the initial EIA; a comprehensive assessment of environmental, cultural and community impacts needs to be carried out through scientific research and frequent communication with regulators (local, state, and federal resource agencies, etc).

To support the siting decision, surveys and studies of the proposed project site should be carried out to assess the presence or absence of:

- National and state parks, wildlife refuges, wilderness areas, monuments, historic sites, and special designation areas e.g., trails;
- State wildlife management, scientific and natural areas, nature conservancy preserves;
- Rare/unique natural resources; and
- Avian nesting areas and migration routes.

The EIA for a wind-diesel project takes place in a broad political, social and economic context. It is one step in a wider decision making process, and is generally written to provide authorities with the following information:

- A full description of the project development – this will outline construction, operation, roads, grid connection, decommissioning, etc
- A statement of objectives, including clear targets and proposed indicators of success;
- A description of the existing environment at the project site;
- Project justification, including evaluation of project alternatives;
- Description of environmental impacts – economic, social and ecological considerations, including the consequences of not undertaking the project;
- Identification of any mitigation measures that may be implemented to minimize environmental harm and/or enhance the environment; and
- Propose possible monitoring and reporting measures – a description of the stakeholder communication/consultation process undertaken.

Effective environmental management over the life of the project should ensure sustainable operation of the facility. Other considerations for the EIA include studies on: topography, soils, geologic and groundwater resources, surface water and floodplain resources, and adverse human and environmental effects that cannot be avoided.

7.2 EIA Best Practices: Mitigating Environmental Impacts

EIA Implementation

Before a location is selected, the siting process for a wind development should include steps to minimize both environmental and social impacts. Of concern are the effects on the surrounding human environment including noise, visual resources, wildlife, habitat, travel management, and soil and water resources. The scoping and responsibility for carrying out the EIA is detailed in table 7.1.

Table 7.1. The EIA Best Practices: Who should implement? When should they happen?

Process	Implementation	
Environmental Impact Assessment • Noise • Visual impact • Local/migrating wildlife • Ecological assessment • Traffic and roads • Soil erosion and water quality	Who	• Developers should take the lead in conducting the actual assessment and gathering necessary information to ensure comprehensiveness; • Regulators and local communities should assist in providing the necessary and desired information.
	When	• Initial outreach to gather information from the community and written documentation should begin early in the planning phase; • Note that the environmental assessment should be used to inform siting, and construction activities, as well as any post construction monitoring and decommissioning.

Noise

WD systems produce noise through a number of different mechanisms which can be roughly grouped into mechanical and aerodynamic sources:

- Mechanical components – the gearbox, generator and yaw motors each produce their own characteristic sounds; other mechanical systems such as fans and hydraulic motors can also contribute to the overall acoustic emissions. Mechanical noise is radiated by the surfaces of the turbine, and by openings in the nacelle casing.
- Aerodynamic – the interaction of air and blades produces aerodynamic noise through a variety of processes as air passes over and past the blades; this tends to be broadband noise, but is amplitude modulated as the blades pass the tower, resulting in a characteristic ‘swoosh’.

The subjective audibility of a wind turbine generator is also highly dependent on the background sound level. Generally, wind turbines radiate more noise as the wind speed increases, but so too does the background sound (moving trees, grasses, etc.) – the latter somehow masks the sound of the turbine.

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Recommended Practices: Noise Mitigation

The following are suggested as best practices for future wind energy developments, presented somewhat in order of implementation:

1. Developers need to comply with any local, state and federal approval processes with regard to noise pollution. During initial planning stages for a potential wind project site, it is important to identify all potentially critical receptors for noise, including residences, institutions, etc.

2. Educate the local community with respect to the sound generated by wind turbines – an essential public relations exercise at the early stages. Community involvement needs to continue throughout the project.

3. The EIA should establish certain minimum distance between the project placement and any residential or potentially sensitive receptors.

4. Ambient sound levels should be monitored at the receptors to assist in defining criteria and to provide a benchmark for any sound measurements following start-up of the operations.

5. Accurate sound power data for the wind turbines is necessary for the predictions, and is readily available from leading manufacturers. The sound power data should be based on measurements conducted in accordance with IEC 61400-11[1], and be provided as a function of wind speed. The specific numeric criteria for the sound pressure level produced by wind turbines vary from state to state.
   It is recommended that an analytical, prediction-based standard that relies on sound powers from IEC 61400-11 using the propagation model of ISO 9631-2 be utilized. The standard starts with 40 dBA at night in quiet rural areas, but adjusts the limit for acceptability as a function of wind speed. The criteria are presented in A-weighted decibels below:

Table 9.2: Recommended sound criteria for wind turbines.

Wind speed (m/s)	4	5	6	7	8	9	10	11
Wind turbine noise criteria (dB)	40	40	40	43	45	49	51	53

[1] International Electrotechnical Commission (IEC) Standard: IEC 61400-11, *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques,* Edition 2.1, Nov. 2006. Obtainable at: http://www.iec.ch/

Visual Amenity

Concern

The aesthetics of utility-scale wind energy facilities have emerged as important factors in public opposition to wind development projects:

- The large size, strong color contrast, unusual geometry, as well as the very large aerial extent of wind farms, can result in visual impacts;
- Hazard navigation warning lights can also cause visual impacts; and
- Shadow flicker caused by moving blades can cause visual impacts.

Best Practices

Visual impact assessments and visual impact mitigation may not be required by regulatory agencies, but should be conducted by developers during the planning process, and continue throughout the siting and development phases of a project, and used as part of the public engagement process. Overall, the visual impacts must be considered largely a subjective matter.

The following aspects are important factors in controlling the visual impact:

- *Color* – the common practice is to color the turbines with a matte finish so as to reduce reflection.
- *Scale, Spacing* – the key challenge regarding the height of the turbines is the visual dominance of the structure(s) on the landscape and/or surrounding properties. The spatial design of the wind project should be developed in context with the existing landscape so as to be in balance with what previously exists, such as numbers of other human-made structures, surrounding vegetation, etc.
- *Lights and signage* – placement of lights and signs on turbines can affect their visual impact. The only lighting installed on wind towers should be flashing red beacons at the top of the nacelle unit as required by aviation regulations. Other established practical guidelines for turbine lighting should be followed.
- *Wires and cables* – above ground grid connections will typically increase the visual impact on the landscape compared to if the cables are trenched. With respect to small turbine structures it is important to clearly mark guy wires, if present.
- *Shadow flicker* – occurs when the sun is low in the sky and the blades of a wind turbine cast a shadow over a window in a nearby house and the rotation of the blades causes the shadow to flick on and off. Wind turbine control software is available that can turn the relevant turbine off at these times. The developer may wish to consider the economic impact of use of this mechanism. Other mitigation measures could include the provision of screening measures, where this is acceptable to the relevant householder.

Local and Migrating Wildlife

Concern

It is essential to identify and avoid areas where legally protected wildlife are present or potentially present, including known migration corridors and breeding areas for these species.

The main concern in Alaska with construction and operation of wind turbine projects is the effect on wildlife through[2]:

1. Collision with turbine structures, blades and anemometer guy wires;
2. Electrocution by contact with electrical power lines;
3. Direct loss of habitat; and
4. Indirect habitat loss due to increased human presence, noise, etc.

Recommended Practices

WD projects affect a relatively small footprint on the land they occupy, thus the above concerns should mostly be minor. Recommended best practices:

1. Developers are urged to consult the USFWS guidelines as a basis for developing specific protocols to address the survey needs that should be scientifically robust even as the particular needs of natural communities and species differ by site.
2. It is essential for the developer to identify and avoid areas where legally protected wildlife are present or potentially present.
3. Developers should consult with appropriate resource management agencies (e.g. federal, state, and/or local) and reach out to local conservations groups and landowners to determine where there are environmental sensitivities so as to avoid sensitive wildlife habitats.
4. Developers for large projects need to plan for post-construction surveys and adaptive management plans to reduce collision mortality. Establish baseline data about numbers, usage, population trends, etc. from literature and expert interviews.
5. Developers should refer to the Migratory Bird Treaty Act (MBTA)[3] and the Bald and Golden Eagle Protection Act (BGEPA)[4] that together protect numerous bird species from incidental or accidental mortality. Executive Order 13186 provides additional protection for migratory bird habitats from federal actions including e.g., project permitting or approval.

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[2] *Permitting of Wind Energy Facilities: A Handbook*, National Wind Coordinating Committee (NWCC), 2nd Ed., August 2002. Available online: http://www.nationalwind.org/publications/siting.aspx

[3] Summary from Federal Wildlife Laws Handbook: *The Migratory Bird Treaty Act* 16 U.S.C. §§ 703-712, July 3, 1918, as amended 1936, 1960, 1968, 1969, 1974, 1978, 1986 and 1989. http://alaska.fws.gov/ambcc/ambcc/treaty_act.htm

[4] Bald Eagle Management Guidelines and Conservation Measures: The Bald and Golden Eagle Protection Act. Online available: http://www.fws.gov/midwest/eagle/guidelines/bgepa.html

Ecology

Natural Vegetation and Habitat Loss

The significance of vegetation loss (typically about 3 – 5% of the total surface area) associated with a wind project usually depends on the size of the area disturbed and whether rare or sensitive native plants are affected.

The extent of vegetation disturbance and loss typically depends on:

- The wind speed, duration, and direction;
- Relative height and placement of the turbines; and
- Site topography and layout of access roads.

Best Practices

Environmental effects to surrounding ecosystems can be mitigated or minimized through proper planning and consideration of equipment use.

1. It is recommended that the developer undertakes ecological survey work at the appropriate time of year to take account of the seasonal nature of some of the potential impacts under consideration.
2. The footprint on vegetation and habitat should be limited to the creation of an access road, transmission line and to the site;
3. Environmental remediation should be part of post construction work;
4. Some wind projects include agreements or requirements to remove or prevent the re-growth of nearby trees that disrupt wind flow and reduce available energy. These often must be controlled to allow native vegetation to be re-established.

Soil Erosion and Water Quality

Concerns

1. Uncontrolled runoff from construction sites can cause short-term increases in turbidity and siltation in nearby watercourses.
   Spills resulting from project construction and operation activities, such as refueling heavy equipment, may also impact water quality.
2. The public health and safety concerns – typically associated either with the release of emissions or solid and liquid wastes.

Best Practices

With appropriate precautions, the impact of W-D projects should be minimal:

1. Hydrological assessment of the impact of the proposed development on water courses, their quality and quantity may be necessary.
2. Setback requirements – these provide an adequate buffer between wind generators and consistent public exposure and access.
3. Project developers are urged to consult widely on guidelines for controlling erosion and runoff.

7.3 Site-Related Design Constraints and Emerging Risks

Aviation Safety

Concerns

The Federal Aviation Administration (FAA)[5] is in charge of determining, among other things, where towers more than 200 feet tall can and cannot be placed if there are nearby airports. Such obstructions must be illuminated so that aircraft can easily identify and avoid them, while at the same time, minimizing any impact of the illumination on surrounding communities.

Best Practices

Marking and lighting of wind turbine structures is intended to provide day and night conspicuity. It is recommended that the developer takes the following recommendations into consideration with regard to the techniques for obstruction marking and lighting wind turbine installations:

1. Color – wind turbines should be painted in bright white whenever possible, as the color itself acts as an effective daytime early warning device (though white may negatively intrude on the visual impact). Other colors that have been encountered, such as light gray or blue, appear to be significantly less effective in providing daytime warning.

2. Lighting – employ only red, or dual red and white strobe, strobe-like, or flashing lights, not steady burning lights, to FAA requirements for visibility lighting of wind turbines, permanent met towers, and communication towers.
   Only a portion of the turbines within the wind project should be lighted, and all pilot warning lights should fire synchronously.

The developer should have documentation verifying that the system is in compliance with applicable air safety regulations concerning lighting, color and markings, height and location. Determination of 'No Hazard to Air Navigation' must be received from the FAA; generally, one is required to file Form 7460-1 (Notice of Proposed Construction) with the FAA for any structure taller than 200 feet (61 m) above ground level[6].

[5] Wind Turbine Lighting Requirements are published by the FAA in Advisory Circulars. The latest Obstruction Lighting Advisory Circulars can be found at the FAA web site, www.faa.gov

[6] The FAA does require notice on structures under 200 feet depending on proximity to an airport.

Electro-magnetic Interference

Main Issues: Effect on Radio, Radar Systems, and Telecommunications

Wind turbines can interfere with communication systems that use electromagnetic waves. This is caused mainly by the turbine blades, which sometimes scatter the signals as they rotate. Such scattering can weaken or otherwise interfere with telecommunications signals (microwaves, televisions, and radar or radio transmissions). Electromagnetic interference (EMI) mainly affects television reception, aircraft navigation and landing systems, as well as microwave links, with television reception being the most common problem. These impacts are amplified by proximity to the turbine. However:

- EMI effects on FM radio, cellular phones and satellite services are very unlikely to occur;
- There is no electromagnetic interference from small turbines due to their size and also the materials from which they are built (small turbines are in fact used in to power remote telecommunication systems and military facilities).

Best Practices

Signal interference with electromagnetic communications can be avoided and mitigated through proper planning and responsible site selection:

1. EMI is a site-specific issue, so it is recommended that an onsite assessment be performed to identify any effects on telecommunication services in the area as well as the interference zones to establish appropriate setback distances.
2. Most of the concerns can be addressed through design (e.g. keeping the turbines away from line of sight of transmission towers) or mitigated with technological fixes (e.g. devices amplifying radio signals put in place by wind energy developers).

Impacts or radio waves and electromagnetic interference are typically addressed by other regulatory bodies (federal and state) and the developer is advised to communicate with these bodies. However, whether there would be unacceptable interference should be determined through site specific analysis. It is recommended that a consultation zone be established – a zone where the developer would require consultation with the appropriate agency responsible for the system.

Emission Issues

The main types of local pollution from diesel generation power plants in the United States are summarized in Table 7.3.

Table 7.3. Health and environmental effects of air emissions[7].

Air Pollutant	Fossil Fuel Sources	Health & Environmental Impacts	Other Considerations
Carbon Dioxide (CO_2)	Produced during combustion by the oxidation of carbon in diesel	Carbon dioxide is the principal greenhouse gas causing global warming	Combustion of fossil fuels also contributes to emissions of other greenhouse gases: methane (CH_4) and nitrous oxide (N_2O)
Sulfur Dioxide (SO_2)	Produced by combustion of sulfur in oil-fired plants	Exacerbates heart disease and chronic lung disease, especially in children, older adults, and asthmatics	A major contributor to acid rain, particulate matter, and regional haze.
Nitrogen Oxides (NO_x)	Produced during combustion by the oxidation of nitrogen in oil and the oxidation of nitrogen in the air	At high concentrations, can cause adverse respiratory effects in children and adults	• Precursor to ground-level ozone (smog) that is formed by photochemical reactions with Volatile Organic Compounds (VOCs). • Ozone is a lung irritant that affects people with respiratory diseases, including asthma, especially during outdoor exercise. • A contributor to the formation of particulate matter.
Particulate Matter (soot)	Produced by combustion of fuels and by reactions of SO_2 and NO_x	• Can cause or aggravate heart or lung diseases. • Causes regional haze and visibility problems	Can be transported long distances and acts as a carrier for toxic substances, including trace heavy metals

Note:

- Generator-emitted noise may also be considered a pollutant to the environment. However, modern acoustic enclosures largely eliminate this problem, and any remaining noise concerns at specific sites should be addressed early in the process.

- Both NO_x and SO_x can be minimized on many engines using minor engine adjustments, as per with manufacturers' recommendations.

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[7] Emissions references are from the U.S. Environmental Protection Agency, *Compilation of Air Pollution Emissions Factors (AP42)*, Chapter 1.1, updated 2007. The air emission health effects descriptions are based on U.S. EPA, *Air Quality Index: A Guide to Air Quality and Your Health*, EPA-454/K-03-002, 2003.

EPA Tier 4 Requirements

The US Clean Air Act requires that *New Source*[8] *Performance Standards* (NSPS) be established to control emissions from new stationary sources. An NSPS requires these sources to control emissions to the level achievable by best demonstrated technology, considering costs and any non-air quality health and environmental impacts and energy requirements.
Two groups of standards have been adopted for gen-set emissions:

1. For manufacturers – manufacturers are required to emission certify stationary diesel gen-sets beginning with model year (MY) 2007;
2. For owners/operators – are responsible for emission compliance for gen-sets acquired during the transitional period before MY 2007

The Tier 4 regulations as applied to power generation call for 50-90% reductions in particulate matter (PM) emissions and up to 90% reduction in NO_x emissions, depending on the kW rating of the generator set.

In meeting the Tier 4 standards, emission reductions can be achieved through the use of control technologies – including advanced exhaust gas after-treatment – similar to those required by the 2007-2010 standards for highway engines. While the requirements to certify diesel engines generally shift the burden of air quality compliance toward manufacturers[9], end-users must be aware of local or site-specific regulations affecting their operations.

Harsh Climate Conditions

Especially for Alaska it is important the take harsh climate conditions (often internationally referred to a hostile climate conditions) into consideration. As the diesel generators are typically housed in temperature controlled powerhouses harsh climate conditions would generally – in addition to possible outside diesel fuel storage issues – be a concern for the wind turbines and meteorological sensors of an arctic WD system.

Today any commercial wind turbine manufacturer will be able to supply their wind turbine with a cold climate package that may or may not include a blade heating option. However, the down time – and the corresponding loss of energy – caused by cold climate phenomena may be quite considerable.

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[8] New sources are defined as those whose construction, reconstruction, or modification begins after a standard for them is proposed.

[9] Most diesel generator manufacturers (including Caterpillar, Cummins, Deere, Detroit Diesel, Deutz, Isuzu, Komatsu, Kubota, Mitsubishi, Navistar, New Holland, Wis-Con, and Yanmar) have responded by utilizing innovative technologies to achieve compliance with Tier 4 requirements.

There are three general issues important to the operation of wind turbines in cold weather that need to be examined in the design or at least in the phase preceding the installation:

1. The impact of low temperatures on the materials' physical properties;
2. The ice accretion on structures and surfaces; and
3. The presence of snow in the vicinity of a wind turbine.

If not attended they would mean prolonged period of inactivity required for safety purposes or due to inability of the turbines to perform satisfactorily.

Very cold temperatures

Low temperatures affect the different materials used in the fabrication of wind turbines, usually adversely. Very cold temperatures may in arctic applications influence both wind turbine material properties and lubrication demands. The user should keep in close communication with the turnkey contractor to make sure harsh climate conditions are properly covered in the proposed system (cold climate package provided by the turbine manufacturer).

Icing

Icing represents the most important threat to the integrity of wind turbines in cold weather. It is advisable that power production be maintained in moderate icing for the following reasons:

- Minimize downtime and benefit from the more favorable winter winds;
- To keep the rotor turning so as to limit the ice growth to leading edge part of the blade that is likely fitted with ice protection equipment.

The icing likely to form on wind turbine blades is of two kinds: glaze and rime.

Glaze ice – is the result of freezing precipitation striking turbine surfaces at temperatures below the freezing point. Glaze is rather transparent, hard and attaches well to surfaces, and may be so extensive that it causes unbalance of the rotor, forcing the controller to shut down the wind turbine (to prevent overload and/or excessive power production) until the glaze ice is melted.

Rime ice – occurs when surfaces below the freezing point are exposed to clouds or fog composed of supercooled water droplets. An opaque coating of tiny, white, granular ice particles forms, caused by the rapid freezing of supercooled water droplets on impact with wind turbines and meteorological equipment. Rime often leads to wind speed sensors and wind vanes being frozen solid, preventing the wind turbine and system controllers from acquiring necessary data. The sensors may be heated (at a considerable cost) but even heated sensors may not always be able to overcome rime ice.

8 Permitting Practices and Stakeholder Consultation

Introduction

In developing the permitting process as a resource tool to assist stakeholders in the regulation of wind energy developments within Alaska, a balance of factors needs to be considered. This section clarifies which (if any) legal framework exists for the utilization of wind energy in the prospective case of isolated power supply, by considering the following issues:

- Policies & incentives for wind energy;
- Rights & conditions to build/erect/install wind energy equipment;
- Rights & conditions to connect to busbar / grid / substation;
- How and by whom are the policies, incentives, rights and conditions determined?
- Which standards & regulations apply?

Most permitting processes for energy facilities, including wind-diesel systems and associated transmission amenities, consist of five basic phases:
1) Pre-application, 2) Application review, 3) Decision-making,
4) Administrative and judicial Review, and 5) Permit compliance.

The **Appendix** correlates to the permitting practices in this section, and include the step-by-step process necessary to obtain permits, approvals, and authorizations from local, state and federal agencies (where applicable). In addition, relevant contacts for regulatory agencies are included to aid in both planning permission and consultation.

Chapter Contents

The table below lists sections included in this chapter.

8.1 Planning Permission

Albeit there is a broad range of regulatory approaches available for consideration by wind industry developers, the challenge in regulating these developments lies in obtaining a balance between encouraging developments, maintaining public welfare and safety, and avoiding negative environmental or socioeconomic effects.
There is currently a need for more clarity of legislation in this area both from communities where this technology is being implemented and from developers that are making the large investments.

Typical Steps in Permitting

The following are primary considerations in identifying the nature of permitting process required:

- Applicable existing laws and regulations;
- Location of the wind turbines and associated facilities or equipment;
- Need for transmission lines and access roads;
- Size of the wind-diesel project;
- Ownership of the project;
- Land ownership; and
- Funding (federal and state sources).

Typically, wind projects are required to obtain a permit from one or more government agencies. Permitting entities at the federal, state, and local levels may have jurisdiction over a wind development, and the developer should contact all relevant permitting agencies or authorities early in the project planning and development process. The number of agencies and the level of government involvement will depend on a number of factors particular to each development.

Local Permitting Authorities

Typically, primary permitting is undertaken by local jurisdictional entities (local planning commission, zoning board, city council, or county board of supervisors or commissioners) that regulate through zoning ordinances. In addition to local zoning approval, permitting may require a developer to obtain some form of local grading or building permit to ensure compliance with structural, mechanical, and electrical codes.

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State Permitting Authorities

State permits may be required for siting or review responsibilities for wind developments in addition to local or conditional use permits. State authorities may include natural resource and environmental protection agencies, state historic preservation offices, industrial development and regulation agencies, public utility commissions, or siting boards.
State law may supersede some or all local permitting authorities; where there is state level regulation there may be a lead agency to coordinate the regulatory review process or a one-stop siting process under one agency. Whether the permitting jurisdiction is state or local, wind projects are still subject to local and state environmental policy acts.

Federal Permitting Authorities

The federal government's role in regulating wind power development is limited to projects occurring on federal lands or projects that have some form of federal involvement (where federal dollars are spent). In this case federal land management agencies may be both the manager and the permitting authority. In such cases, projects must comply both with state and local requirements and with any applicable federal laws. These laws often require pre-construction studies or analyses of proposed projects, and possibly project modifications to avoid adverse environmental effects.
Depending on the type of actions and the potential for impacts, the federal agency may have to prepare an environmental assessment or environmental impact statement for the project before it can act.

Table 6.1 provides a brief overview of the key stages each state or federal agency is involved in (**√P** denotes the "primary" agency involved in stage).

Table 7.1. Project phases and agency involvement index[1].

Project Stage	ACMP	ADEC	ADF&G	ADNR	ADOT&PF	FAA	NMFS	SHPO	USACE	USFWS	Local Gov.
Site Evaluation		√				√P		√P	√	√P	√
Project Design		√				√		√	√	√	
Permitting and Consultation	√P	√	√	√	√	√	√	√	√	√	√
Construction		√	√			√		√		√	√
O&M						√				√	

[1] *Alaska Wind Energy Development: Best Practices Guide to Environmental Permitting and Consultations*, Alaska Energy Authority, September, 2009. For meanings of agency acronyms see Glossary.

Institutional and Legal Framework

It is necessary to clarify which (if any) legal framework exists for the utilization of wind energy in the prospective case of isolated power supply. A fundamental aspect of managing risk associated with a wind power scheme is to have processes in place that ensure compliance with all relevant laws, policies, permits, agreements and codes of practice. These may include, but are not limited to[2,3]:

- Policies & incentives for wind energy;
- Rights & conditions to build/erect/install wind energy equipment;
- Electricity supply regulations – rights & conditions to connect to grid;
- Environment protection legislation and associated permits;
- Conservation and threatened species legislation;
- Cultural heritage and indigenous rights legislation;
- Occupational health and safety legislation;
- Federal, state, and local government policies;
- Corporate law requiring financial and environmental reporting; and
- Voluntary commitments and signed agreements.

The legal basis of a W-D project will be constituted by most or all of the following documents: Landowner Agreements; Project Finance Documentation; Planning Restrictions; Environmental Impact Assessment documents; Turbine Supply Agreements; Power Purchase Agreements; and Interconnection Agreements.

Management Plan

A management plan is highly recommended, and may be required as part of the application process, to clarify the responsibilities of the owner/developer in various stages of project lifetime. It may include the following:

- Construction (and design) details;
- Operational and maintenance requirements;
- Traffic management with details on volumes, frequencies, and haul routes of construction vehicles;
- Process for complaints, and any required mitigation measures and required monitoring;
- Safety protocols to reduce the risks associated with ice throw and blade/turbine failure;
- Emergency management plan; and
- Decommissioning details.

[2] N-E. Clausen, H. Bindner, S. Frandsen, J. C. Hansen, L. H. Hansen, and P. Lundsager, "Isolated Systems with Wind Power: An Implementation Guideline," Risø-R-1257(EN), Risø National Laboratory, Roskilde, Denmark, 2001
[3] WWEA Sustainability and Due Diligence Guidelines, October 2005.

8.2 Stakeholder Consultation

Stakeholders

Changes to communities associated with wind development impact a range of long held community values including aesthetic and quality of life factors. It is useful to recognize that these concerns can, at least in part, be mitigated with financial, participatory, and consultative mechanisms.

These guidelines on stakeholder consultation highlight a number of needs:

- To identify all the relevant stakeholders;
- To provide them with the information they need;
- To be open and honest about what an individual project involves; and
- To engage with stakeholders in a variety of ways, enabling everybody to have their opinions heard and their ideas taken seriously.

Throughout rural Alaska, the W-D developer will primarily be dealing with native corporations as the landowner. Typically there will be two corporations: regional and local, and these have to be consulted with regard to ownership of both surface and sub-surface land rights. When considering easements through native allotments, it should be considered best practice to avoid these areas due to the legal work necessary to transfer ownership or lease ROWs. Other than the landowners, stakeholders in the project will include the purchaser, producer, lending institutions, construction contractor, equipment suppliers, and O&M organizations. For the purposes of the Guidelines it is possible to split stakeholders into three main groups: Statutory consultees, strategic consultees, and community stakeholders.

Table 7.2. Stakeholder categories for a wind-diesel project.

Statutory Consultees	Strategic Stakeholders (Non-statutory Consultees)	Community Stakeholders
• These are pre-defined by regulation, and are bodies with which developers are obligated to consult; • Include state and federal agencies and local authorities, electricity retailers, network service providers and regulators, the general public, etc. • While developers will need to ensure they follow the correct statutory processes for these organizations, they can also be included in non-statutory consultation.	• Organizations, whether at a federal, state, or local level whose support of or opposition to a development would be significant; • Groups that have particular information or expertise to offer. • Examples include the landowners, local utilities, Department of Defense, conservationists, Sea Fishery Committees/commercial fishermen, Greenpeace, etc.	• Individuals or organizations who are interested because they live in the community the development will affect; • Interested individuals; • Representatives of residents associations, community councils, church groups,, etc; • Local companies, local fishermen's organizations, educational interests, • Recreational groups/clubs, dog mushers, etc.

Consultation Issues

It is recommended that proactive community consultation occur to establish effective and locally appropriate approaches to the regulation of wind development. This consultative and participatory approach should be extended to specific developments, sites, and opportunities that may be proposed for the community. The economic, social and environmental effects associated with a specific wind development also need to be considered, not in isolation, but in relation to local and broader impacts associated with conventional Alaska energy sources.

The following issues can form the basis of community (or stakeholder) consultation with developer:

Economic and Commercial Considerations

- Effects on employment and the local economy;
- Effects on leisure pursuits;
- Effects on other users of the area.

Social Issues

- Effects on employment (other than the purely economic);
- Effects of environmental changes on local residents (including visual, noise and traffic);
- Health and safety of the workforce, local communities and members of the public.

Environmental Issues

An environmental assessment can be informed by determining where there are environmental sensitivities and other local concerns, including:

- Wildlife habitats and plant communities/species;
- Designated areas and proximity of protected areas;
- Birds – distribution, disturbance, displacement;
- Visual impact , landscape and amenity value;
- Noise, vibration, lighting; and
- Cultural resources and archaeological heritage.

Local citizens and businesses can be a wealth of knowledge about non-protected species and other local environmental sensitivities. A larger developer might wish to consider establishing a project-specific website, which would provide up-to-date material for interested parties.
The reviewing agency may use the results of the NEPA review to clarify requirements for mitigation and monitoring to address the project’s environmental impacts.

PART III

RECOMMENDED BEST PRACTICES
FOR
SITE DEVELOPMENT AND OPERATIONS

9 Sustainable Infrastructure Development in Cold Environment

Introduction

Permafrost is soil, sediment, and rock that stays at or below the freezing point of water for two or more years, though ice is not always present. Permafrost can be either continuous or discontinuous and when present is covered by a thin active layer that seasonally thaws during the summer. Climate change can degrade permafrost by affecting its extent and the degree of seasonal thawing.

The most favorable areas for the production of wind energy are often located where the climatic conditions are severe and unpredictable. In order to improve the performance of wind power systems in this environment, some issues need to be examined carefully. Climate change in interior Alaska is affecting permafrost freeze and thaw processes; permafrost degradation in many areas of Alaska has the potential to dramatically affect surface features such as soil and vegetation, as well as surface and subsurface hydrology. At the same time, changes in soil, vegetation, and fire regime can impact the rates and extent of permafrost degradation.

The foundations for most wind turbines are shallow bearing foundations. Manufacturers require that foundation systems meet certain stiffness requirements, to ensure longevity of the turbines and prevent resonance. Special soil considerations are required in relation to the cyclic weakening or degradation in strength as a result of dynamic loading, with concrete commonly used in wind tower foundations to provide mass and dampening.

Permafrost is a major consideration in siting of W-D systems as it has a direct cost implication on foundation design and access road development. Due to the unique conditions of Alaska, particular costs are incurred during the installation of a wind energy system. For example, the wind turbine foundations are designed to have minimal impact on the frozen tundra, and often the installation must take place during the winter to ensure that the frozen ground will support the weight of the cranes, pile drivers, and forklifts.

Chapter Contents

9.1 Permafrost Considerations

Permafrost Challenges

Foundation design in remote areas and places with permafrost is an additional challenge for wind projects in Alaska. Wind towers must be designed to meet dynamic loading, vibrational loading, and stiffness requirements. Many site-specific considerations are required for proper foundation design.

However, the ground in most of Western Alaska (where most of the installations are) is often not suitable for shallow bearing foundations. Remote locations, lack of local aggregate, and cold-climate make concrete challenging and expensive.

Best Practices in Foundation Design

When possible, choose locations that are not suspected of having permafrost features. Most of the Yukon-Kuskoquim delta is permafrost that is only slightly below freezing temperatures so avoiding poor quality soils may not be possible. Drill core samples early in the planning stage to understand what challenges may be encountered. Specialized foundation designs will increase the project timeline and cost. An assessment of soil types and other geotechnical features will be necessary for design of any foundation.

When permafrost cannot be avoided, consulting with a company that has experience designing foundations in permafrost conditions is required.
In general, a raised pad foundation on piles can result in a successful installation. Degradation to permafrost results in the piles either jacking upward or sinking. Either way, a catastrophic failure from the unleveled foundation would result. The following issues must be addressed when constructing on permafrost:

- **Structural** –The foundation must be able to bear the moment acting on it during peak wind conditions, not have a resonant frequency near the turbine operating frequency, and meet stiffness requirements. Dynamic modeling of this type of foundation is recommended to ensure the specifications set by the turbine manufacturer can be met.
- **Cooling** – Keeping frozen soils frozen keeps the properties of the soil stable. Passive cooling with thermosyphons may be necessary.
- **Concrete** – One option is pre-casting foundations and shipping them to the site, with the added advantage of quality of cast concrete.
- **Economics** –The cost of installation on permafrost may prohibit installation in that area.

10 Commissioning

Introduction

The definition of 'commissioning' is not standardized, but generally covers all activities after all components of the W-D system are installed. Following completion of the building and installation period and before handover of the project, an overall inspection and commissioning of the works is carried out.

Commissioning inspections are performed by representatives of the contractor and the final owner, with participation from the local network operator. The commissioning may involve an elaborate testing and monitoring plan, but the main objective is to verify that the system is complete, correctly installed and functioning properly. Normally a commissioning procedure is formulated in co-operation with all the parties involved.

Commissioning tests will usually involve standard electrical tests for the electrical infrastructure as well as the turbine, diesel generators, and inspection of routine civil engineering quality records. Commissioning of an individual turbine can take little more than two days with experienced staff. Careful testing at this stage is vital if a good quality W-D project is to be delivered and maintained.

It is quite common that a number of defects are discovered during the first commissioning inspection, resulting in a defect or 'snag' list. Actions to clear this list are decided between the parties concerned and, if there are serious defects, may result in a second commissioning inspection being required.

Approved commissioning and handover is usually related to final project payment.

Chapter Contents

10.1 Commissioning and Handover

Performance Expectations

A system is ready to be commissioned once all wind-diesel components have been constructed and installed. Fully commercial wind-diesel systems should expect to have a predictable time period for commissioning. However, non-standard wind-diesel systems typically can have an ongoing commissioning period which delays full functionality of the W-D system for sometimes up to two years. The commissioning process can and will vary from site to site – but ultimately should result in meeting specific requirements as dictated by the client or funding entity.

During commissioning all wind turbine safety devices and system protection should be tested over a variety of wind and load conditions. Initial and ongoing performance testing should include a holistic set of measurements including wind turbine power, system voltage, system frequency, and diesel fuel consumption. The client should receive confirmation of proper operation of all controls and communication systems. Until confirmation is received that the power quality parameters are within acceptable limits and that all systems check out with full functionality, a system cannot be said to be commissioned. As developers begin pushing the envelope of cutting edge technologies extended commissioning times can be expected which incurs additional risk on the client and community if not approached correctly and with caution.

Certain parameters will have a clearly defined limit of what is acceptable while other variables will be more relaxed. The client should detail out these expectations with the contractor prior to commissioning so that performance requirements are understood. The quality of supply is generally broken down into the obvious areas: frequency, voltage, brown outs, black outs, etc.
The specified acceptable tolerances at each site can vary.
Some examples of parameters are included below.

Under normal operating conditions:

- Frequency +/- 0.5 Hz
- Voltage +/- %5 rated

Under fault conditions:

- Frequency +/- 5Hz
- Voltage +/- 10%

Fault conditions must not exceed 5 seconds.

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Power Quality

- Power Factor
- System Frequency
- System Voltage

Wind Turbine Factors

- Wind Turbine Minimum Capacity Factor
- Wind Penetration
- Wind Turbine Availability

Diesel Factors

- Diesel Efficiency (Min/Avg/Max)
- System Efficiency (Min/Avg/Max)
- Heat Recovery (% or BTUs)
- Ramping
- Load-Sharing
- Plant and Engine Temperatures

Heat Recovery

- Switching Speeds

SCADA Systems

- Data Acquisition
- Data Storage
- Remote Access

Additional Items

- Fault ride through capabilities
- Diesel Fuel Offset (electrical and thermal)
- Acceptable Number of Blackouts/Brownouts (not more than 1.5 per year)
- Acceptable Number of System Failures
- Acceptable Harmonic Distortion

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Reliability Issues

W-D System Infrastructure

After commissioning, the W-D project will be handed over to the operations and maintenance crew. A typical crew will consist of two people for every 20 to 30 wind turbines in a wind farm. For smaller wind farms there may not be a dedicated O&M crew but arrangements will be made for regular visits from a regional team. Typical routine maintenance time for a modern wind turbine is 40 hours per year. Non-routine maintenance may be of a similar order.

A complete set of 'as built' drawings, should be provided to the client along with full operation and maintenance manuals. The building permits obtained in order to allow the construction of the wind project may have some ongoing environmental reporting requirements, for example the monitoring of noise, avian activity or other flora or fauna interest. Similarly there may, depending on the local regulations, be regulatory duties to perform in connection with the local electricity network operator. Therefore, in addition to the obvious operations and maintenance activity, there is often a management role to perform in parallel. Many wind projects are the subject of project finance and hence regular reporting activities to the lenders will also be required.

Components

Component suppliers need to provide a commitment that their equipment will work to a certain level of reliability per year. For example, a major component should be online 99% per year. This availability clause or reliability clause includes time offline for servicing. These sorts of clauses should be open for negotiation and where the supplier fails on the clause then they are penalized financially. Likewise, where the supplier exceeds the expectations of the clause, they can be compensated financially.
Once tight regulations exist appropriate guidelines must be put in place to distinguish what responsibilities lie between system component suppliers.

Models

Economic and performance models should be requested prior to any contractual agreements. Interested suppliers and developers should supply pertinent models e.g., HOMER, to demonstrate the reduction of diesel fuel and anticipated savings based on assumptions that are obviously negotiable during the contractual processes. An audit could be carried out by an independent group (such as a University or State program) that could review the actual delivered system's performance *vis-a-vis* the initial model supplied.

11 Distribution System Management

Introduction

Grid Codes have been agreed in many jurisdictions. Amongst other things, they set out the technical obligations of generators connected to the system. Some of the requirements for the W-D system include:

- Transient stability is the most onerous requirement to meet.
- For requirements which can only be met by wind turbines by reducing output, and therefore losing energy (such as frequency response and reserve capacity), it would be economically most efficient for these requirements to be met by conventional generation, possibly through some kind of market mechanism.
- Detailed dynamic models of wind turbines will be required.

The W-D system is expected to perform control of the following to ensure stable power:

- Frequency regulation;
- Voltage stability;
- Reactive power control; and
- Transient stability;

Chapter Contents

The table below lists sections included in this chapter.

11.1 Power System Operation

Power Quality

'Power quality' should more correctly be termed 'voltage quality', as it is concerned with the quality of the voltage on the network as seen by the customer. For wind turbines, there are three main issues.

1. **Harmonics**

Any power electronic converter will result in some harmonic voltages on the network. However these can be controlled to acceptable levels, at a cost, and the more modern wind turbine contain converters, which do this remarkably well.

2. **Flicker**

This phenomenon is the result of rapid fluctuations in power or reactive power, causing rapid fluctuations in voltage, sufficient to cause perceptible 'flicker' of lighting. Wind turbine suppliers are aware that this is an issue that has to be controlled; modern variable-speed types produce very little flicker.

3. **Voltage steps**

This is similar to flicker, except that it is produced by sudden events such as the starting or stopping of a wind turbine. The resulting voltage step can be perceptible to other consumers, but more importantly could result in the voltage at some point on the system falling outside the statutory range, until voltage control equipment on the network can operate.

Black Start

Wind turbines cannot reliably contribute to getting the system running again after a catastrophic event. Some other generators can be paid for this ability, but this will not result in a significant economic penalty for wind.

Ancillary Sertvices

Costs of Ancillary Services

Ancillary services are those functions provided by generators in addition to energy production.

It is not necessary to estimate the effect on ancillary costs, as it is assumed that the conventional generation running in the no-wind case is also running when wind is added, and is therefore available to provide the normal level of ancillary services (to a good approximation). This may be an expensive operating philosophy at high wind penetrations. If some of this conventional generation were shut down, wind could provide replacement ancillary services at zero additional cost, except for reserve and frequency regulation

11.2 Maintenance

Best Practices

The wind energy industry is the fastest-growing segment of renewable energy production. Both wind turbine installation and turbine maintenance are **high risk tasks** and safety considerations must be a main priority.
The best practices do not advise on how and when to perform maintenance programs – these are detailed in the manufacturer's package – but how best to avoid accidents for the personnel. The following should be observed:

Turbine Installation:

- Ladder systems should have built-in vertical fall arrest systems.
- Worker harnesses should be comfortable, lightweight, and have multiple anchor points to last through long days on the job.
- Equipment should incorporate tool-carrying accessories to keep productivity high.
- Crews should use hydration systems that clip onto harnesses, easing the burden of working at heights and preventing dropped object injuries.

Maintenance:

- Safety equipment will be the same as for tower installation (above)
- Maintenance and repair of control mechanisms for the blades will involve accessing the hub of blades from the outside of the nacelle. This dramatically increases the potential for a fall.
- Specialized fall protection equipment (vacuum anchor) will need to be used if a permanent anchor is not available.

Rescue:

A major difference in W-D system for Alaska is the required rescue equipment since most projects are in remote areas.

- On-site rescue teams need rescue equipment that is quick to set up and easy to use.
- A rescue plan should be developed prior to beginning any work on a tower and should outline the common hazards (fire or complete mechanical shutdown).
- Workers must have proper rescue training, which should include a mixture of classroom and practical experience.

In most cases the turbine area is identified as a permit-required confined space. As a result, workers should:

- Have confined space training.
- Utilize a portable gas monitor and test the atmosphere before entering a confined space. (Learn how to calibrate your instrument)
- Ascertain all of the crew's portable gas detectors are in working order.
- Always test for oxygen levels.
- Perform continuous testing for flammable and toxic gases on entry
- Utilize a unit that conveys alarm annunciation in multi-sensory ways, audibly, visually, and tactilely.

11.3 Health and Safety Management

Public Safety Considerations

Installations of W-D systems require added safety measures due to the nature of the materials, and it is recommended that standard safety precautions and practices be implemented throughout construction.

The project development process requires identification of hazards and management of risks to public safety. Risk assessments combine consideration of the hazard presented by the specific installation/location (taking due account of all risk control measures) and the nature and frequency of public exposure. The process must provide assurance that the risks from the proximity and layout of turbines in relation to areas used by the public are acceptable.

Specific issues on which public safety assurance is appropriate include:

- Turbine structural integrity;
- Fire/flame spread;
- Ground stability;
- Lightning;
- Falling objects;
- Ice throw/shedding;
- Public access;
- Site security and signage (for vehicles); and
- Leisure craft traffic.

Some Recommended Best Practice Guidelines

1. Developers are expected to adhere to the highest standards and ensure that contracts for design, procurement, construction, commissioning and operation are written so as to promote safe practices and avoid clauses that may compromise Health and Safety. This is fundamental to the development and maintenance of a strong safety-first culture within the W-D industry.
2. Ensure that throughout the life cycle of the W-D project, the workforce are involved in improving Health and Safety standards as far as reasonably practicable through appropriate consultation, suitable training, competence assessments and by adequate supervision.
3. Aim to promote experience transfer between members so that good and best practices can be disseminated through learning from accidents, incidents, near events and operating experience.
4. Generally, there should be a common standard for safeguarding persons from the inherent dangers that exist from the electrical and mechanical plant; safety issues given by the manufacturer should be observed.

12 Recommended Performance Values

Chapter 12 is still a work in progress, and ACEP is in the process of obtaining pertinent data from various sources. This Chapter will list various recommended performance values for typical W-D systems in Alaska against which developers and operators should use as benchmark data. The wind turbine and/or diesel performance data shall be based on manufacturer input, experience with wind power systems in Alaska, and empirical analyses. This Chapter will grow in size and relevance as additional W-D power systems and monitoring equipment are accessed.

13 Data Management

Background

The need for high quality data is mostly self-explanatory. Developers and purchasers of W-D systems for installation in remote and isolated locations must have a high level of confidence that the system will have high reliability and perform as claimed or specified. Detailed Information for such system analysis will provide higher confidence in any findings. The degree to which this confidence can be confirmed will be influenced greatly by the verification of performance and reliability achieved through a rigorous and well-documented testing and evaluation program.

Developing a baseline of high quality data enables project stakeholders to gain such confidence but also to internally scrutinize said performance in order to optimize system functionality. In order to establish such a baseline, a large sample of high resolution data needs to be acquired. Typical SCADA systems will collect high data sampling rates (0.1-1.0 Hz) and then create longer averaging intervals (10 min - 1 hr) for summaries as needed. In addition, the SCADA systems can record alarms and faults.

Health monitoring of W-D systems is another critical reason for data collection. Real time operational data is used to better understand the health of existing systems. Data collected for this purpose will include high resolution performance data, derived data, operational, and observational data. Operational and maintenance logs should be recorded in detail and stored in digital format for ease of access.

Chapter Contents

13.1 Data Processing and Quality Assurance

Common Data Definitions

High Resolution: Data that is collected at a fast rate providing the greatest detail. Example: 1 data point per second or 0.1-1.0 Hz.

Low Resolution: Data that is collected and stored at lesser intervals in order to minimize storage requirements, e.g., 1 data point every 10 min -1 hr.

High Level: Data that has been analyzed or is derived.

Low Level: Data that is raw and has not yet been manipulated or analyzed.

Database: A collection of information that is organized so that it can easily be accessed, managed, and updated. However, not every collection of data is a database; the term database implies that the data is managed to some level of quality.

Metadata: Structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource. Metadata is often called data about data or information about information.

Best Practices

There are numerous components to having a successful data management protocol. Developing a plan for data stewardship is key. There must be a form of quality control in place and there needs to be serious consideration to a centralized data storage mechanism whether through an online server and/or hard drive back up. A common data format, such at netCTF (Network Common Data Form), will allow for multiple systems and users to interface with each other. NetCTF is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of scientific data.

Data Processing

The development of a robust data processing system is time consuming, but once a process is developed further streamlining will enable enhanced and efficient analysis of future hybrid systems. The specific challenges include:

- Developing mechanisms to handle large, high resolution, low-level, and raw data files;
- Developing routines to process the raw data;
- Developing processes to ensure a high quality of data; and
- Determining scripts for calculating derived data.

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Raw File Handing

The data collected from any diesel hybrid system when sampled at the necessary rate can consume significant amounts of storage capacity. One example of a small diesel hybrid system is Ugashik which has a small number of channels – 18 data channels that are sampled every 5 seconds. Each day this adds up to 17,200 data points per channel and for all channels this equals 3 MB. In a larger system, such as in Unalakleet, with 6 wind turbines and 2 generators, a file taking one measurement per second for 24 hours would create a file of approximately 30 MB. A database of this size can easily be compromised and slow to process, especially with a year's worth of such files.

The management and storage of these types of files is entirely possible but needs appropriate design considerations. There are numerous difficulties inherent in the design especially considering that each data set tends to have a unique design. For example, the descriptions units for each column may vary for each dataset. Datasets are not documented at all so there is no metadata. This simply emphasizes the need to have a well thought out data management system.

Matlab is one of the commercially available software for processing raw data. Matlab contains sophisticated routines that can easily handle the massive raw files. The general protocol involves:

1. Selecting the raw files to be processed;
2. Converting the LabView format/SCADA format to native Matlab matrices;
3. Running quality assurance algorithms for each channel;
4. Writing the filtered data to a netCDF file;
5. Generating overview graphs of each channel's daily time series;
6. Generating a summary file listing daily averages, standard deviations and min/max values for each channel; and
7. Producing graphs plotting daily averages and standard deviations vs time for the complete set of files.

These steps should be undertaken per site every month to assure data quality. Points (1) through (4) are done using parallel computing routines, such that 100 files (300MB) can be processed in about 1 minute on a top of the line laptop computer.

Common Data Points

- The configuration of each W-D system will vary on how much power performance data should be collected from each generator, wind turbine, and storage device or secondary load. On the purely wind side, meteorological factors are important to collect because they lend key insight to the wind turbines overall performance. These factors should include wind speeds and direction, ambient temperature, and humidity, and will provide clues to the wind regime and shed light onto low performance due to icing events.
- Generator fuel consumption is not the easiest to accurately obtain but every effort should be taken to match timestamps from fuel consumption with collected system data.
- Operational and maintenance data is not always acquired through the traditional SCADA system and is often recorded in handwritten logs. This data should be translated into a digital format for ease of access. Three tables are provided below as examples of what values are critical for health monitoring, optimization, and evaluation.

Fig. 13.1. Sample data tables for a W-D system.

Generator Values	
Hertz	PF
KW	RPM
Volts A-B	Fuel GPH
Volts B-C	Fuel Gallons
Volts C-A	Engine Water Temp
Volts A-N	Running Timeout
Volts B-N	Oil Temperature
Volts C-N	Engine Water Temp Return
Amps A	Exhaust Temp
Amps B	Efficiency
Amps C	Start Count
PF	Engine Hours

Bus Values
KVAR
Peak Demand
Hertz
PF
KWH
Boiler KW
Boiler KWH
Wind KW

Wind Turbine Values
Online Hours
Fault Status
KW
Volts A
Volts B
Volts C
Amps A
Amps B
Amps C
Hertz
Outdoor Temp
RPM
KWH
Wind Speed
Wind Speed 1 Min
Wind Speed 10 Min

Quality Assurance

Every data set will contain periods of unreasonable data. For example this can manifest itself in negative power readings on the generator which need to be removed from the time series of the affected channels. When data clearly turns unphysical during certain episodes, steps are to be taken to determine if data points need to be removed.

Example

In Ugashik, ACEP searched through the generator signal to determine whether the signal contained data points below a threshold of -0.03 kW (using a value smaller than zero, as small deviations below zero are reasonable for a shut off generator). If any data point within the given window (100 data points) is below the threshold, all data points within the window centered around the actual faulty data point are discarded and their time stamps recorded. All data points are discarded within the window to ensure that there is a good buffer between real signal and faulty signal. Using the recorded time stamps the corresponding data points in all power, current and voltage signals are discarded. This process highlights the need for high resolution data. Typically 15 minutes averages are accepted as sufficient, however, if the data is faulty then the average is also faulty yet this is much more difficult, if not impossible, to detect without the raw data.

One caveat of this procedure is that time series that need to be processed in this way ends up having fewer data points. This, in turn, means that the derived averages are not truly daily averages anymore. This is something to keep in mind when doing further analysis with these types of files.

Sample Plots for Ugashik

Fig. 13.2 represents a graph of the daily averages (red) for the current into the controller of the river side turbine in Ugashik with standard deviation (blue) for each day. This graph was derived from the unfiltered data and it can be observed that values for several days are unreasonably large, which is due to the contribution of large oscillation in the signal on these days.

Fig. 13.3 represents the same graph as in Fig. 13.2 but derived from the filtered data. The maximum values are an order of magnitude smaller than in the previous graph and much more reasonable.

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Fig. 13.2. Daily average for current into wind turbine controller at Ugashik.

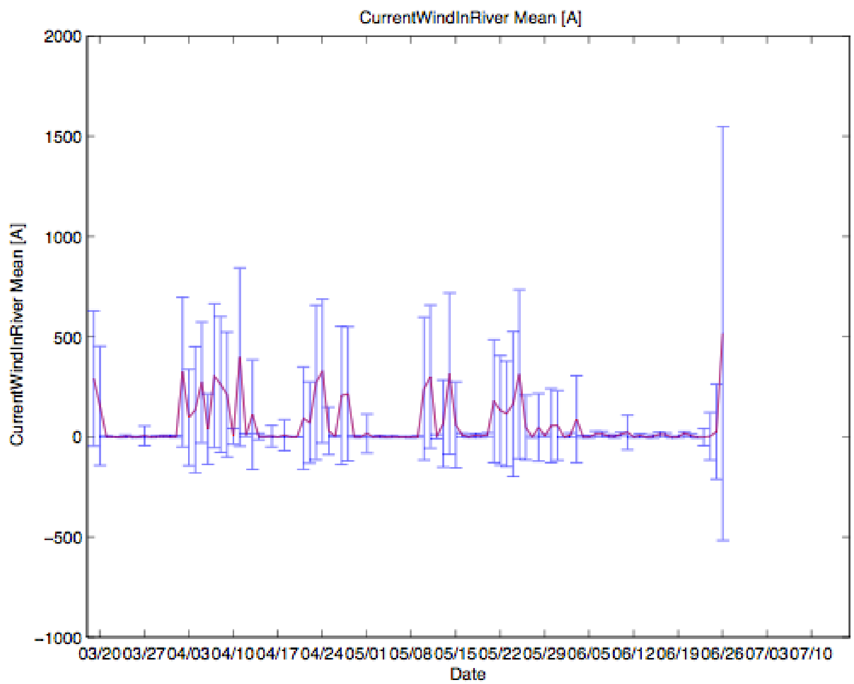
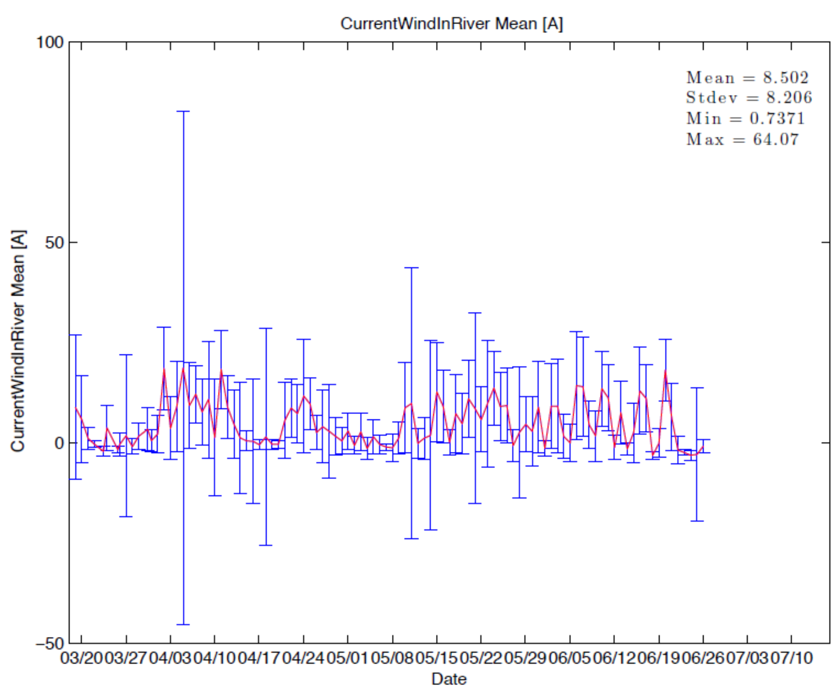


Fig. 13.3. Filtered daily average for current into turbine controller at Ugashik.



14 Decommissioning

Introduction

The underlying premise is that "inactive wind turbines are a bad advertisement for wind energy."

The purpose of the decommissioning plan is to identify the methodology to be used to mitigate potential impacts resulting from the cessation of operation of the facility at the end of the project's useful life. The decommissioning plan identifies the specific project components that will be removed; the nature of the costs associated with the removal of the components and associated scrap value. For a wind-diesel project, equipment removal involves aboveground components (wind turbines, transformers, electrical collection lines, substation, and the diesel generation system), and belowground components (turbine and substation foundations, and underground collection system cables).

The net cost to decommission the project is equal to the cost to perform the decommissioning tasks above, less the resale value of the equipment, either for reuse or for scrap. The greatest value of the removed wind turbines would be realized by selling the wind turbines for reuse, under the assumption that after installation, the turbines would lose 50% of their value in year 1 and then 5% every year thereafter (conservatively estimates).
Total decommissioning costs of the energy facility may not necessarily be offset by the salvage value of the recovered materials.

Chapter contents

The table below lists sections included in this chapter.

14.1 Basics of Decommissioning

Anticipated Life of Wind Turbines

Wind turbines are typically designed to last for over 20 years (employing a proactive maintenance regime can maximize the operational lifespan of the wind turbine generators to a minimum design life of 30 years). Some replacement of parts might be needed in this period, but the main structure is likely to be in place for at least that long. As the wind turbines approach the anticipated end of life, it is expected that technological advances will economically drive the replacement of existing turbines with newer models.

Decommissioning Plan

Decommissioning entails: removal of the turbine, tower, diesel gen-sets, cabling, infrastructure, and foundation to below grade, and site restoration. A wind developer should remove all the turbines and return the site as closely as practicable to its natural state or prior use should the wind energy project cease to produce electricity for a specified period (by agreement with the local planning authority).
Once the wind turbine(s) has been demolished it is vital that land reinstatement be carried out. This entails re-vegetation, including the use of plants endemic to the site. It should be noted that in most cases seeds for native plant restoration are often far more expensive than seeds of plants traditionally used to quickly establish a ground cover. Site clearance should be adequately addressed in the planning agreements accompanying permission.

Generally all visible traces of the project are removed; sometimes the turbine foundations are left in situ as digging them up would cause greater environmental damage than leaving them. The process of removing the wind farm components will involve evaluating and categorizing all components and materials based on their anticipated post-project use. The categories will include recondition and reuse, salvage, recycle, and disposal. The decommissioning and restoration plan includes:

- Removal of above-ground structures (turbines, transformers, overhead collection lines, and the substation, including diesel gen-sets and accessories);
- Removal of below-ground structures (turbine foundations);
- Restoration of topsoil;
- Re-vegetation and seeding; and
- Implementation of a two year monitoring and remediation period.

Trigger for Implementing Decommissioning Plan

Action on the part of the proprietor will be required if the project has not generated electricity for a specified period of time, unless the company produces evidence of mitigating circumstances. Such evidence may include delays surrounding long lead time for spare part procurement, or a force majeure[1] event that interrupts the generation of electricity.

There are two options for dealing with this issue with regard to the facilities and equipment:

1. The Mothball Option – involves suspending all operations and maintaining equipment in working condition until a decision is made to abandon or restore operations. The project can be mothballed for a specified period prior to either restoring it to full operating condition (re-powering), or permanently demolishing the structures.
2. The Abandon Option – involves ceasing all activity, disposing of all equipment and materials, and abandoning the site. This warrants decommissioning the project.

There are two scenarios related to the decommissioning of the project: abandonment during construction, and abandonment during operation. In both scenarios, all decommissioning and restoration activities will adhere to the requirements of appropriate governing authorities and will be in accordance with all applicable federal, state, and local permits. However, it is important for the developer to make provisions and plans for decommissioning of turbines before they are erected. The purpose of such a decommissioning plan is to identify the methodology that will be used to mitigate potential impacts resulting from the cessation of operation of the facility at the end of the project's useful life. The decommissioning plan identifies the specific project components that will be removed; the costs associated with the removal of the components, and associated scrap value.

[1] As used here, a "force majeure" event means instances such as fire, earthquake, flood, tornado, or other acts of God and natural disasters; strikes or labor disputes; war; any law, order, proclamation, regulation, ordinance, action, demand or requirement of any government agency; suspension of operations of all or a portion of the project for routine maintenance, overhaul, upgrade, or reconditioning; or any other act or condition beyond the reasonable control of the developer/proprietor.

14.2 Best Practices for Decommissioning

Decommissioning Process: Wind Turbines

Table 15.1 shows who implements and when to decommission the project.

Table 15.1: Implementing Decommissioning

Process	Implementation	
Decommissioning	Who	• Provisions for decommissioning should be included in policy and regulatory frameworks as much as possible to state that the responsibility and cost of taking down a wind turbine after its use lies with the owner/developer. • Developers should create decommissioning plans in consultation with appropriate regulatory agencies.
	When	Decommissioning plans should be developed during the planning stage and implemented at the end of the useful life of a project's wind turbines and associated infrastructure.

The turbines will be dismantled using standard best management practices. It is recommended that the turbines be dismantled in the reverse of the erection sequence. With the aid of a large (~400-ton) crane along with various support cranes and equipment, the work sequence on the tower site will most likely proceed as follows:

- Assemble and stage crane on pad at turbine;
- Install erosion control measures as required;
- Disconnect electrical connections;
- Remove rotor and block on ground;
- Disassemble rotor;
- Remove nacelle and set on ground;
- Remove turbine tower sections and stage on ground;
- Remove electrical down tower assembly;
- Haul off turbine components;
- Remove wind turbine foundation;
- Backfill foundation;
- Remove electrical collector system (transformers, transmission structures, etc);
- Remove project substation equipment;
- Rehabilitate disturbed areas (suitable grading, re-vegetation; and
- Remove access roads (unless landowner requests they remain).

Description of Work Required: Other Components

Decommissioning of the non-turbine aspects of the project must adhere to the permitting guidelines.

1. The project collector system, substation, and interconnection facilities will be removed and salvaged, recycled, or repurposed to the maximum amount economically practical, providing that applicable regulations are followed.
2. Any trenches or holes that remain after removal will be backfilled, and the surface areas will be rehabilitated.

Some considerations for W-D projects include:

- All necessary permits must be obtained and the generator decommissioning and removal should be in full compliance with environmental regulations and best practice.
- Diesel storage tanks must be emptied of product in the event of decommissioning. Unused product can be used for fuel. Diesel contaminated with water can be burned for energy recovery. Sludge disposal costs must be considered when diesel tanks are emptied.
- Batteries and battery acid (electrolyte), used in power houses and other facilities must be disposed of if appropriately.
- Powerhouse systems must also be considered, e.g., control room, lighting, heating & ventilation systems, compressed air systems, etc.

Salvage and Decommission Costs

Consideration should be given to the setting aside of funds over the life of the project in order to ensure there will be enough money available at the end of the project's life to pay for decommissioning and other reinstatement requirements. A decommissioning formula that reduces the decommissioning and cleanup costs by the salvage value of the wind turbine and related equipment is usually assumed considered.

Wind turbine towers, hubs, blades, and generators are modular, which allows for ease in removal, reconditioning, and reinstallation. Most wind turbine components are of similar composition. Both the tower and nacelle will yield approximately 90% salvageable materials (by weight) with existing technology. The towers consist primarily of steel, which can usually be completely recycled. Most of the nacelle is made of steel and other metals, which can also be recycled. Copper salvage estimates are derived by assuming 5% of the total tower and nacelle weight consists of copper bearing materials.

14.3 Retrofitting and Repowering

Retrofitting

Retrofitting involves replacing portions of existing project facilities so that at least part of the original turbine, tower, electrical infrastructure or foundation is being utilized. Retrofitting best practices include:

1. Use installation techniques that minimize new site disturbance, soil erosion, and removal of vegetation of habitat value.
2. Retrofits should employ shielded, separated or insulated electrical conductors that minimize electrocution risk to avian wildlife.

Remove turbines when they are no longer cost effective to retrofit.

Repowering

Prior to decommissioning, wind turbine sites can be repowered by removing the older, often less efficient, models and replacing them with newer, more economic turbines. Repowering a wind project can save long-term costs and build upon a reliable asset. Re-powering of wind turbine systems is a more likely response to end-of-life turbines than decommissioning, and can include removal and replacement of main turbine elements, such as the generator, and possibly the blades, or the entire turbine.

Planning permission could be required – all the siting and permitting procedures should be followed to enable the repowering process, including environmental impact issues as detailed in Sections 7.2 and 7.3 of the Guidelines. The following are additional best practices for repowering:

1. To the greatest extent practicable, existing roads, disturbed areas and turbine strings should be re-used in repower layouts.
2. Roads and facilities that are no longer needed should be stabilized and re-seeded with native plants appropriate for the soil conditions and adjacent habitat and of local seed sources where feasible, per landowner requirements and commitments.
3. Existing substations and ancillary facilities should be re-used in repowering projects to the extent practicable.

Existing overhead lines may be acceptable if located away from high bird crossing locations, such as between roosting and feeding areas, or between lakes, rivers and nesting areas. Overhead lines may be used when they parallel tree lines, employ bird flight diverters, or are otherwise screened so that collision risk is reduced.