



Wind Energy for Irrigation Pumping

C.P “Case” van Dam

Henry Shlu

Scott Johnson

California Wind Energy Collaborative

University of California, Davis

Irrigation and Nutrient Management Meeting

Salinas, California

26 February 2008



Overview

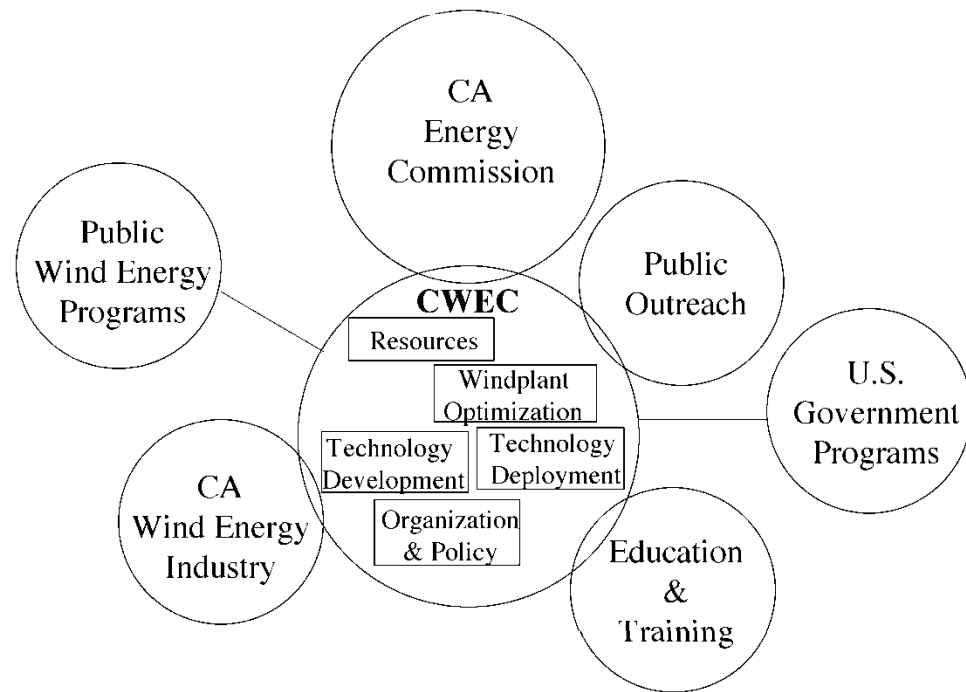
- **A brief history of wind energy**
- **Industry status**
- **System configurations and costs**
- **Economics and purchasing considerations**
- **A local case study**
- **Future opportunities**



California Wind Energy Collaborative

- **Mission statement: Support the development of safe, reliable, environmentally sound, and affordable wind electric generation capacity within the state of California by managing a focused, statewide program of scientific research, technology development & deployment, and technical training.**

- **A partnership of the California Energy Commission and the University of California**
- **Established in March 2002**
- **<http://cwec.ucdavis.edu/>**





E. Mayda

Why Wind Energy?

- **Clean**
 - Emission free operation
 - No waste generation
- **Renewable**
 - Guaranteed “fuel” availability
 - No cost volatility
- **Installation**
 - Rapidly deployed
- **Security**
 - Non-centralized installation and operation
 - No imported fuel requirement
- **Economics**
 - Cost effective energy
 - Local economic benefits

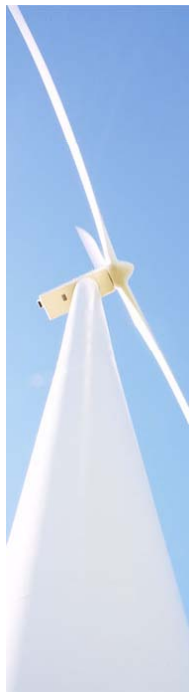


Wind Energy & Farms: A Long History

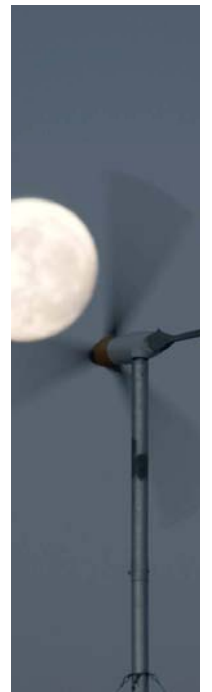
- **Beginning in the 1850s, windmills were commonly used across the country for pumping water**
- **In the early 20th century, small wind turbines were used in rural areas to power lighting and charge batteries**
- **Interest waned with the Rural Electrification Act of 1936**
- **Renewed interest in wind energy in agricultural environments since the 1990s. Causes:**
 - Mature and reliable technology
 - Cost effective
 - Public interest in renewable, clean power



Wind: Big & Small



	Utility-Scale	Small / Distributed
Capacity	1 MW – 3 MW	300 W – 50 kW
Rotor diameter	60 m – 110 m	1 m – 15 m
Total height	90 m – 170 m	< 50 m
Application	Utility electricity generation (supplying the grid)	Powering nearby (on-site) electrical loads



Given the wind resource in this area, we'll focus on small / distributed wind systems.



Wind: Big & Small

Vestas V80, 1.8 MW



Southwest Skystream, 1.9 kW



Small Wind Energy Systems

- Typically 100 kW or smaller
- Residential, business, industrial, agricultural applications
- On-grid, off-grid (including village power)
- Stand-alone, hybrid (e.g., with solar or diesel)



Source: Southwest Windpower



Source: Alfred University

Small Wind Snapshot

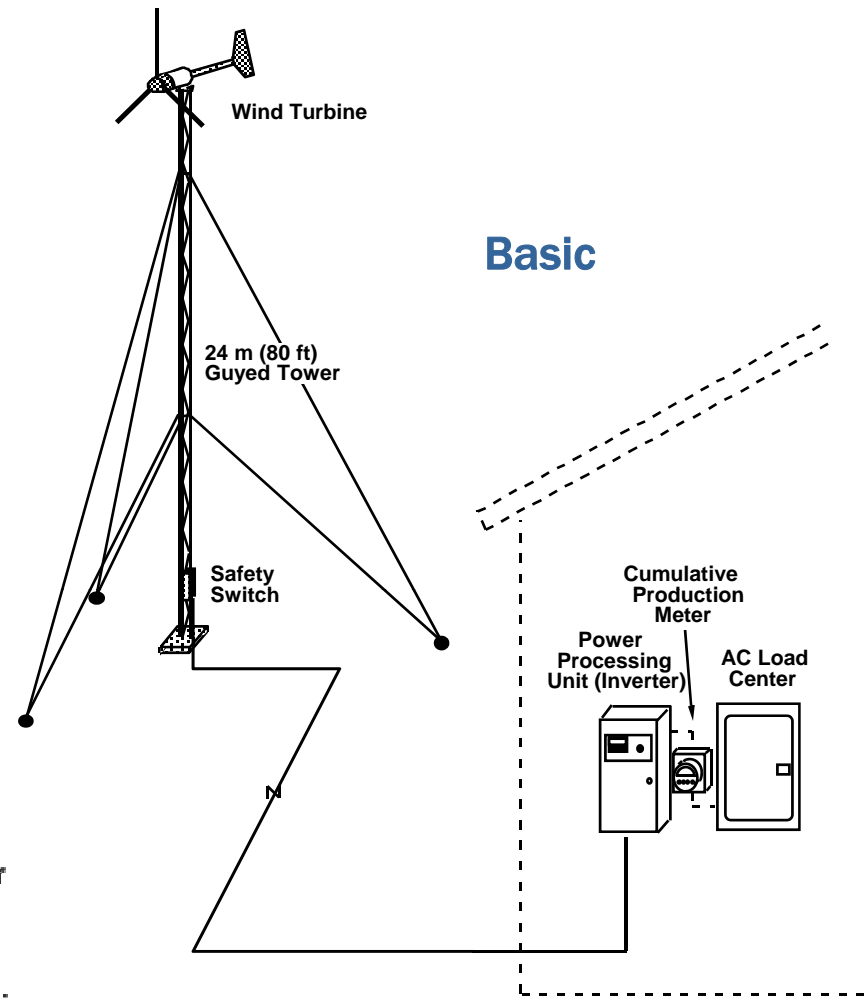
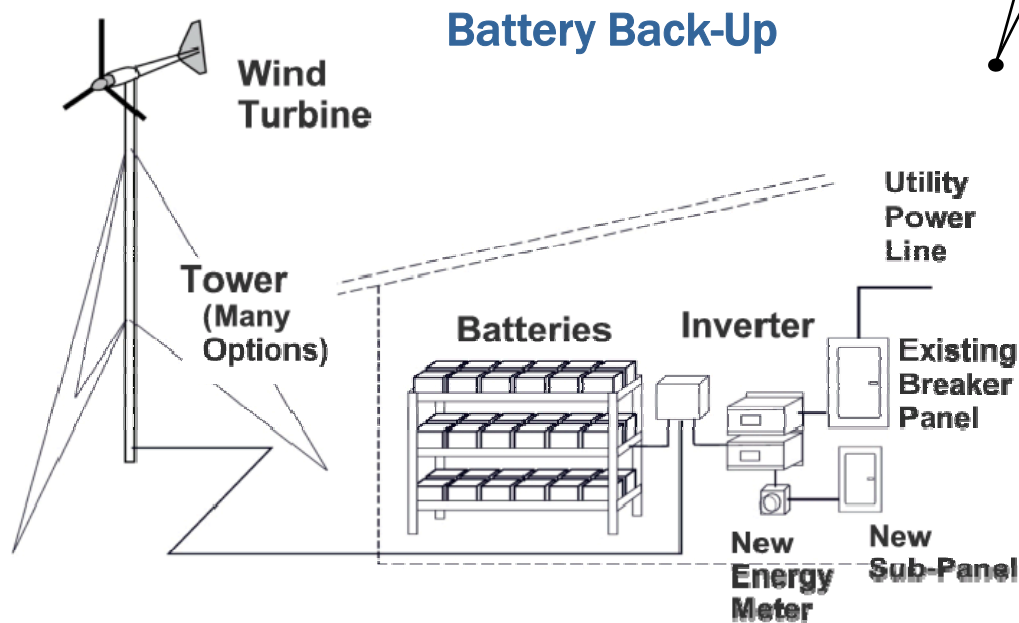
Source: AWEA, 2007

- **As of 2006, there are approximately 2500 grid-connected, residential scale wind turbines (1 - 10 kW) in use in the U.S.**
- **Typically, small turbines are 1 to 10 kW, but range from 300 W to 100 kW**
- **2006 U.S. sales**
 - 6807 small turbines
 - 17.5 MW
 - \$56,082,850
 - 11% on-grid
 - 89% off-grid
 - 98% manufactured in U.S.
- **2006 Sales outside of U.S.**
 - 9502 small turbines
 - 19.5 MW
 - \$61,131,500
 - 97% manufactured in U.S.
- **Manufacturers**
 - U.S.
 - Established: 12
 - Forthcoming: 8
 - Foreign
 - 47
 - At least 13 had sales in 2006
- **U.S. market growth estimated at 14-25% annually**
 - 2004: 30 MW in U.S.



Configurations: On-Grid

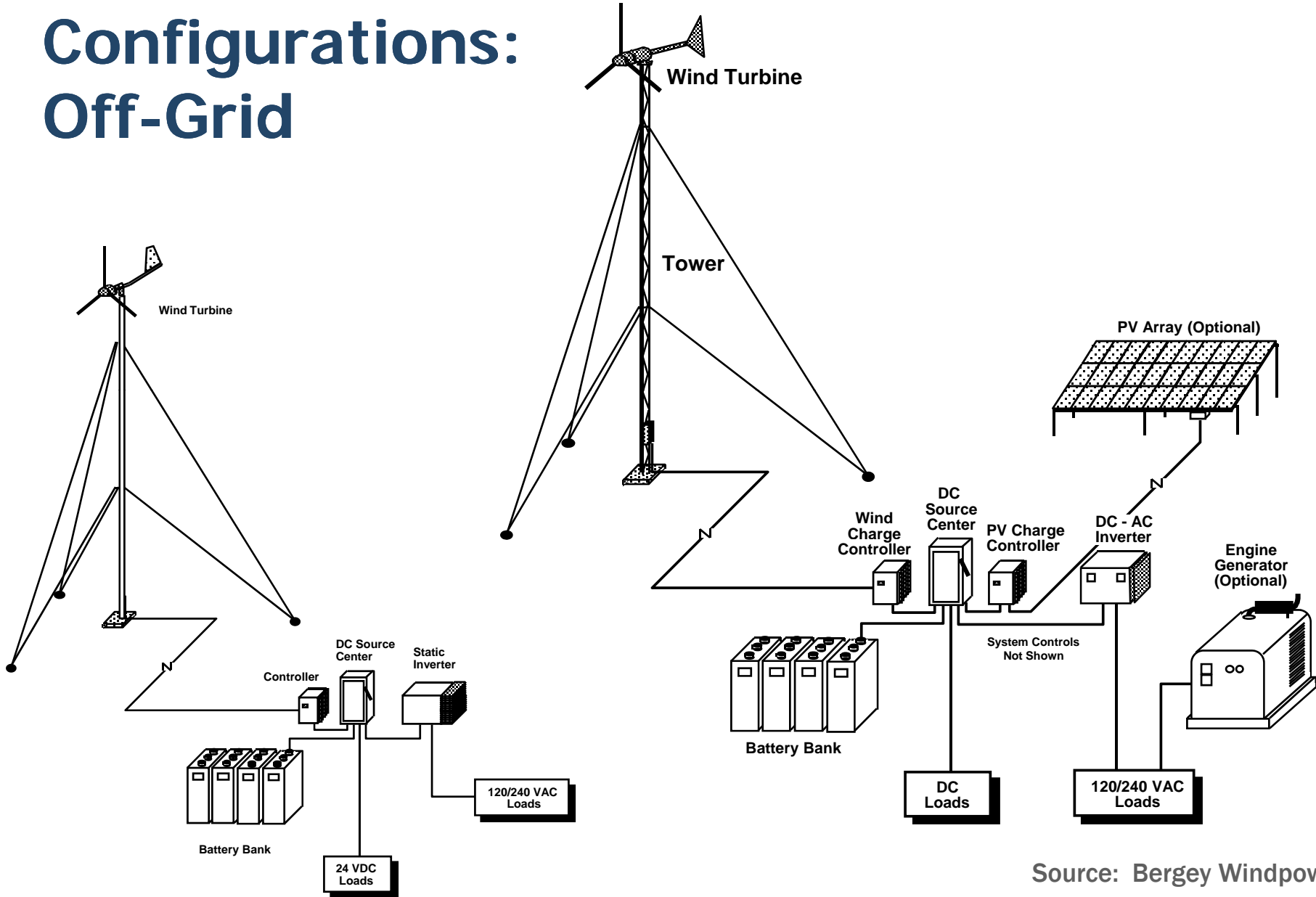
- Can be hybridized with solar or another generation source
- Batteries can provide back-up power and peak shaving



Source: Bergey Windpower



Configurations: Off-Grid



Source: Bergey Windpower



Example System

- **On-Grid Bergey Excel**

EXCEL-S Turbine	\$ 14,900
GridTek 10 Inverter	\$ 8,000
100 ft. Guyed-Lattice Tower	\$ 6,900
Tower Wiring Kit	\$ 930
Shipping & Delivery	\$ 1,200
Foundations	\$ 2,000
Wire Run (250 ft)	\$ 1,750
Electrical Contractor	\$ 1,375
Turbine Set-Up (Inc. Crane)	\$ 1,375
Miscellaneous Costs	\$ 500
Sales Tax (7.75%)	\$ 2,385
Total	\$ 41,315

Does not include permits!



Economics

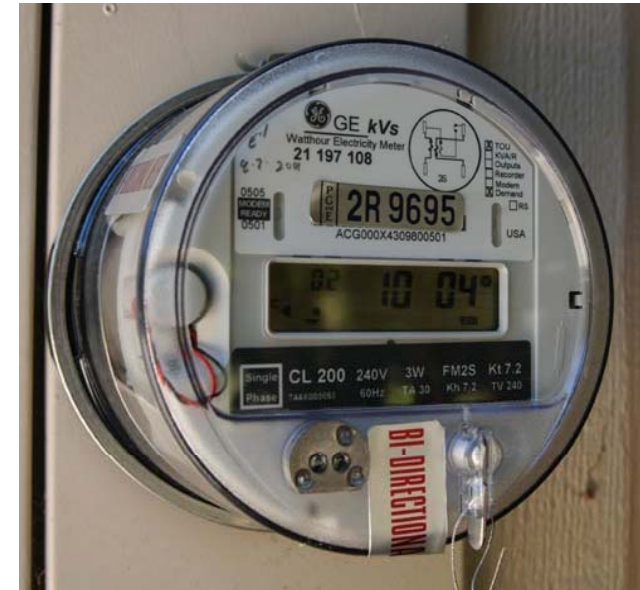
- The economics of utility-scale wind and small wind are very different
- System costs have been fairly steady at **\$5 / watt** (Hingtgen, California Energy Commission), **15¢ / kWh – 18¢ / kWh** (AWEA)
 - Above figures **do not** include incentives
 - Utility-scale wind: \$1.80/W, 4¢/kWh – 7¢/kWh
 - Solar PV: 30¢/kWh (no incentives, sunny climate, source: Solarbuzz); 18¢/kWh (w/ incentives, source: SEIA); \$7.50/W (California, w/ incentives)
- Small wind systems offset the **retail cost** of electricity, not the wholesale cost. In California (PG&E, Oct 07):
 - Residential, single rate: 11¢/kWh – 36¢/kWh (average 16¢/kWh)
 - Residential, seasonal: 7.5¢/kWh – 35¢/kWh (average 21.7¢/kWh)
 - Residential, TOU, Summer, Tier 5: **53¢/kWh**
 - Commercial, A-1: average 17¢/kWh (max 18¢/kWh)
- Net metering and incentives substantially change economics



Net Metering and Co-Metering

Source: http://www.pge.com/suppliers_purchasing/new_generator/solar_wind_generators/standard_e_net/

- **Allows your electricity meter to “spin backward.”**
- **You remain connected to the grid. You are credited for electricity that you generate that you are not immediately using.**
- **Programs vary from state to state, utility to utility. In California:**
 - Eligible for wind turbines under 1000 kW
 - Accounts are balanced on an annual basis
 - Varies with turbine size and electricity rate schedules
- **No financial benefit from annual energy production greater than annual usage.**



Source: Adelman, solarwarrior.com

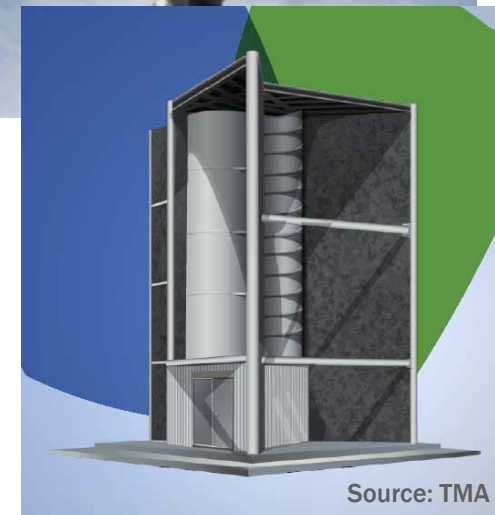
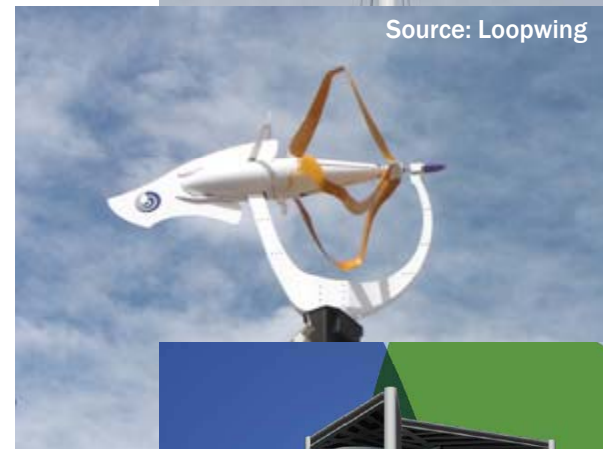
Incentive Programs

- **Self Generation Incentive Program (SGIP)**
 - Eligibility: Systems less than 5 MW
 - 30 kW – 1000 kW: \$1.50 / W
 - > 1000 kW: none
 - http://www.cpuc.ca.gov/static/Energy/Electric/051005_sgip.htm
- **USDA Section 9006: Renewable Energy and Energy Efficiency Program**
 - Grants up to 25% of project costs
 - Loans up to 50% of project costs
 - In its first three years, \$67 million of grants were awarded
 - <http://www.rurdev.usda.gov/rbs/farbill/>
- **California Energy Commission Emerging Renewables Program Rebate**
 - Eligibility
 - Small wind turbines no greater than 50 kW
 - Turbine must be on CEC approved list
 - Grid connected
 - 0 kW – 7.5 kW: \$2.50 / W
 - 7.5 kW – 30 kW: \$1.50 / W
 - > 30 kW: none
 - http://www.energy.ca.gov/renewables/emerging_renewables
- **Program terms are periodically reassessed. Check their websites for the most up-to-date information.**



Caveat Emptor

- There seems to be a new claim for a breakthrough innovation in small wind power every day
- Wind turbine designs have evolved into their current configurations for sound engineering and economic reasons
- Eligibility for California ERP rebates is good indication that a turbine is reliable
 - Compliant with standards or...
 - Demonstrated continuous operation
- “The proof is in the pudding.”
 - The best indication of a good turbine is a history of successful operation



Is Small Wind Right for You?

Two critical steps to evaluate your case, best done simultaneously:

- Check ordinances and file for permits
- Perform energy production and economic analysis.

Do the math!

- Is it windy?
- How much energy (kWh) do I use?
- Configure and size a system.
- Estimate energy production
- Calculate energy savings
- Perform cash flow analysis



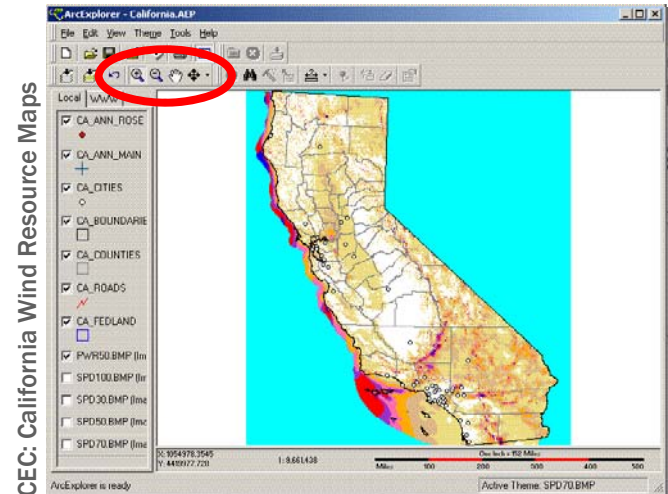
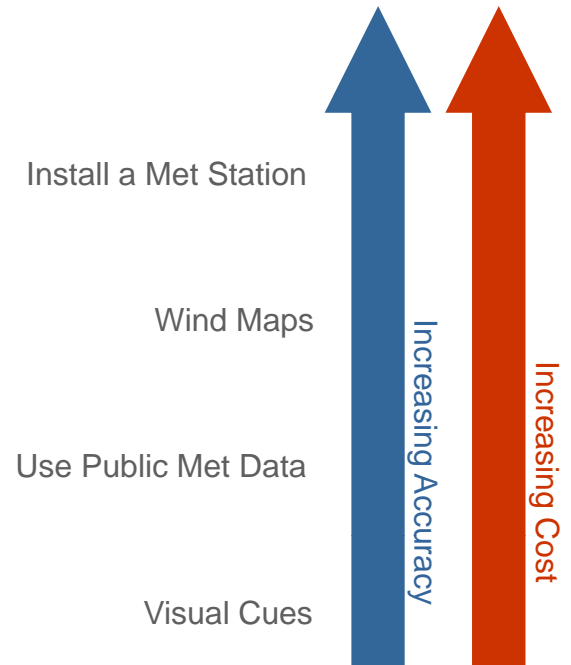
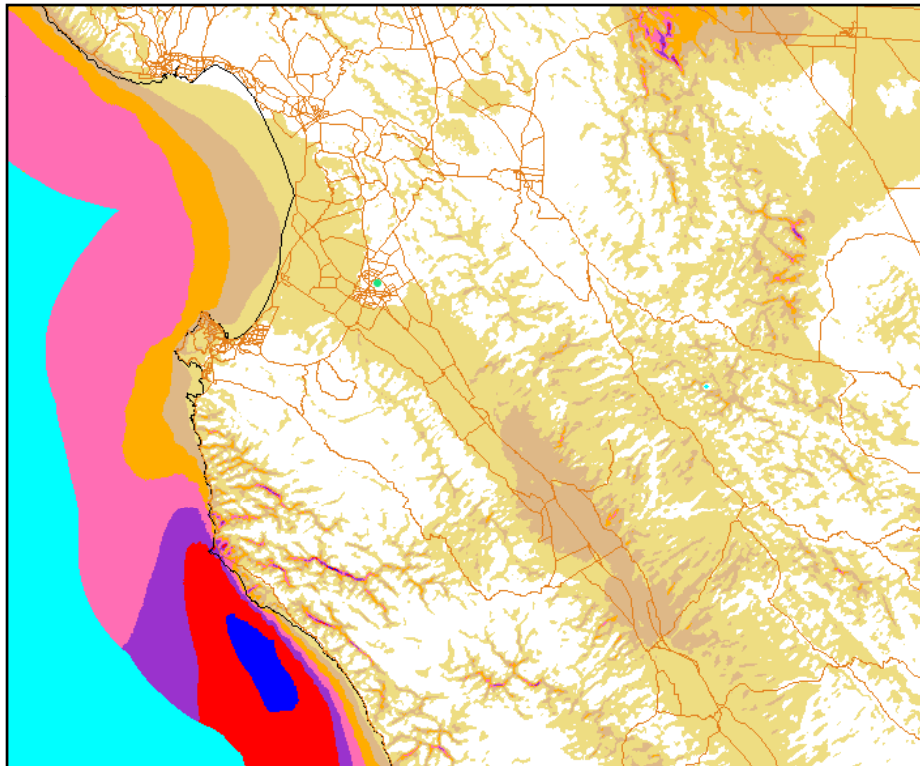
Ordinances & Permitting

- **Like any other structure, a wind energy system requires permits and is subject to local ordinances.**
 - Usually covered in county ordinances and sometimes are found in city ordinances, too.
 - Vary significantly from county to county.
 - Permits can take a long time to process!
- **Monterey County Zoning Ordinance 20.64.120, 21.64.120**
 - Setbacks
 - Minimum of two times the total height from any property line.
 - Minimum of at least 5 times the height from any public road or highway.
 - Minimum of at least 1.25 times the height from any habitable structure.
 - Height
 - Noncommercial system shall not exceed a total height of 50 feet unless the parcel is 10 acres or larger, in which case the maximum total height may be 100 feet.
- **Permitting fees**
 - Vary significantly from county to county: from a few hundred dollars to several thousand.
 - Monterey County has some of the highest permitting fees in California
- **Ordinances on wind energy were often drafted with little experience and may be based on incorrect or dated information. If you don't think that they make sense, talk to your local officials about changing them!**



Wind Resource Assessment

- **Wind resource assessment**
 - Power is proportional to V^3
 - \$\$\$ is proportional to V^3
 - Many methods: varying cost, accuracy



Case Study: Irrigation in Salinas Valley

- **One 450 acre ranch**

- Two wells (two 50kW pumps on each)
 - Conversion: 100 hp = 75 kW
- Each well requires ~ 100kW to operate irrigation system

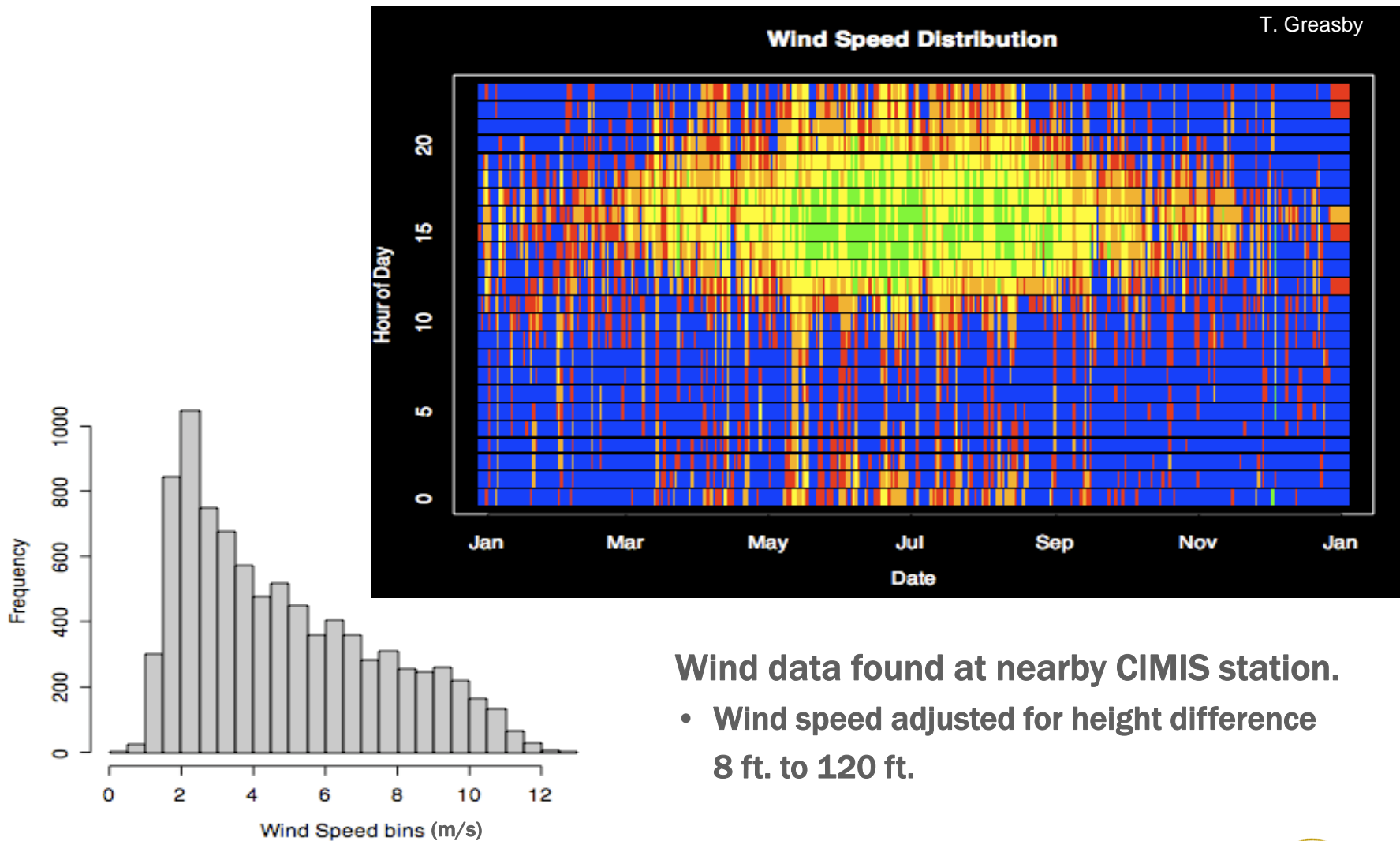
Energy Cost Summary (2007)

	Well 1 (AG-1B)	Well 2 (AG-5B)
Energy Use	100,445 kWh/yr	139,740 kWh/yr
Energy Charge	\$0.15/kWh	\$0.05-0.16/kWh
Energy Cost	\$15,140	\$10,750
Monthly Demand	98 kW	93 kW
Demand Charge	\$4.20-\$6.08/kW	\$4-10/kW
Demand Cost	\$4,760	\$11,400
Total Cost	\$20,110	\$22,450



Wind Resource

When and how fast is the wind blowing?



Wind data found at nearby CIMIS station.

- Wind speed adjusted for height difference 8 ft. to 120 ft.



Choose Wind Turbine

- **Entegrity EW15**
 - Rotor Diameter: 15m
 - Rated Power : 50 kW
- **Tower Types & Footprint**
 - Lattice: 20.5' x 20.5' x 5"
 - Monopole: 22' x 22' x 5"
- **Common Heights**
 - 80', 100', 120'
 - +20' = +\$7500
 - Monopole is significantly more expensive.



Economic Analysis

Well 1 (AG-1B)

COE \$0.15073 /kWh

Entegrity EW15

Rated Power	50	kW
Turbine Cost	\$215,000	
SGIP (Incentive)	\$75,000	
USDA (Incentive)	\$53,750	
Final Cost	\$86,250	
Energy Usage	100,445	kWh/yr
Energy Production	70,020	kWh/yr
% of Energy	70	%
Energy Cost Savings	\$10,554	/yr
Simple Payback	8.2	yrs

Well 2 (AG-5B)

Season	Peak	COE
Summer	OnPeak	\$0.1637
	OffPeak	\$0.0550
Winter	OnPeak	\$0.0611
	OffPeak	\$0.0509

Energy Usage	Energy Charges	Energy Production	Energy Cost Savings
27,189	\$4,450	25,850	\$4,230.87
81,651	\$4,490	27,360	\$1,504.53
19,319	\$1,180	10,520	\$642.56
12,370	\$630	6,290	\$320.35
139,740	\$10,750	70,020	\$6,698

Energy Usage
Energy Production
% of Energy
Energy Cost Savings

Simple Payback

139,740 kWh/yr
70,020 kWh/yr
50 %
\$6,698 /yr

12.9 yrs

Possible ways to increase savings:

- Peak demand shaving to reduce high demand charges
- Energy storage options (batteries, water towers)



CWEC Small Wind Energy Systems Course

- 8:15 - 9:00 am **Welcome and Introduction**
- 9:00 - 9:45 am **Overview of Wind Energy**
- 10:00 - 10:45 am **Resource Assessment & Energy Production**
- 11:00 - 11:45 am **Emerging Renewables Program Rebates**
- 11:45 am - 12:45 pm **Demo stations: small turbine on roof,
analysis tools**
- 12:45 - 1:30 pm **Economics**
- 1:45 - 2:30 pm **System Configurations**
- 2:45 - 3:30 pm **Permitting**
- 3:45 - 4:30 pm **Wrap-Up**



Looking Ahead

- **We believe that a synthesis of wind energy and agriculture in California would yield benefits for everyone**
 - Reduced electricity costs
 - Reduced vulnerability to fossil fuel cost volatility
 - Reduced emissions
 - Reduced dependence on finite fuel resources
- **We're interested in supporting the installation of a wind energy system on a farm in a **pilot demonstration project**. We would assist in the following areas:**
 - Analyze economics: wind power production potential and electricity consumption
 - Navigate local ordinances and permitting requirements
 - Leverage a wide array of federal, state, and industry incentives and grants
 - Install and operate a wind energy system





- **Case van Dam**
cpvandam@ucdavis.edu
- **Henry Shiu**
hjshiu@ucdavis.edu
- **Scott Johnson**
sjohnson@ucdavis.edu

- **California Wind Energy Collaborative**
<http://cwec.ucdavis.edu/>



Supplemental Information



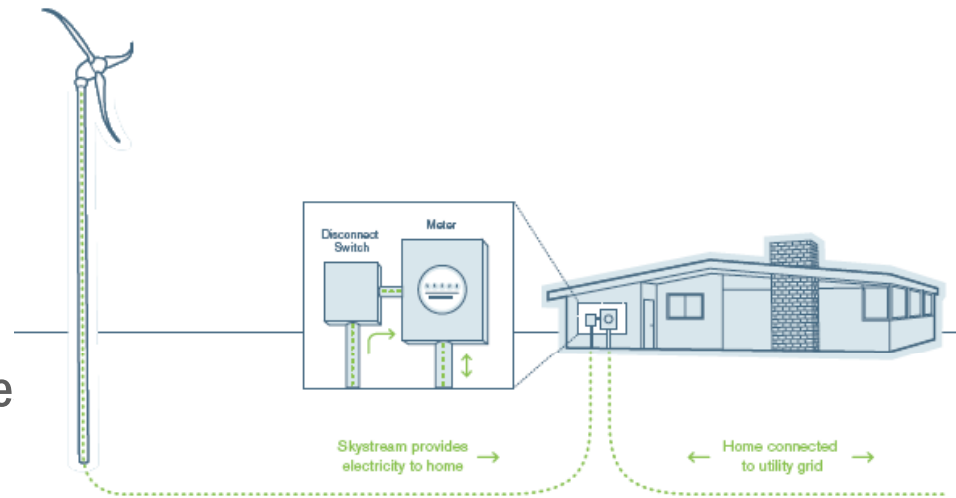
Small Wind System Components

- **Wind Turbine**

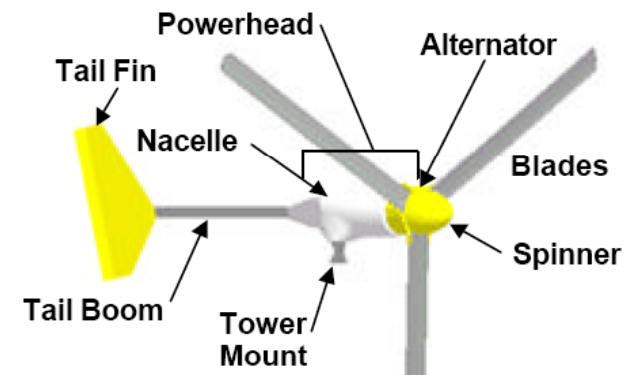
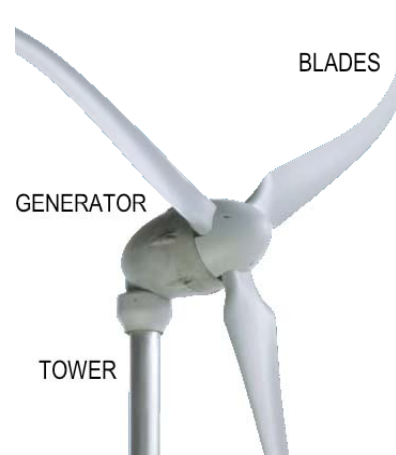
- Blades
- Generator
- Tower
- Tail and furling system (varies)

- **Electrical System**

- Controller
- Inverter
- Disconnect
- Meter
- Batteries (varies)



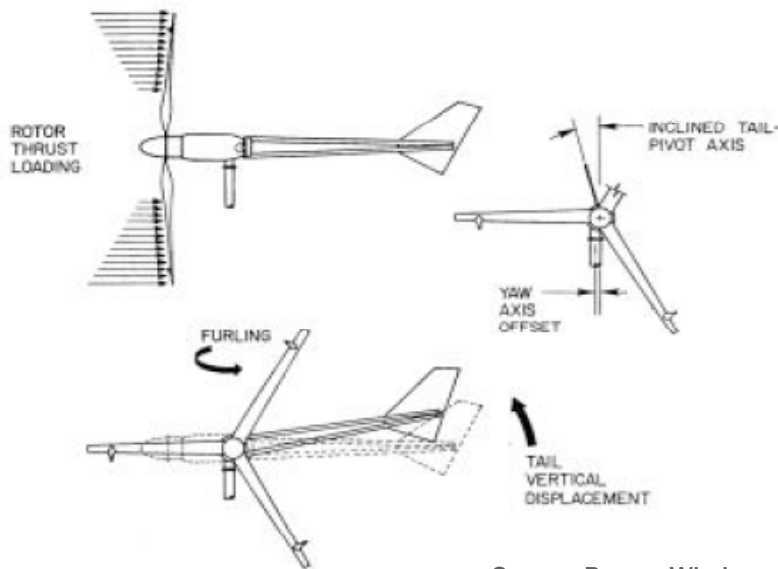
Source: Southwest Windpower



Source: Bergey Windpower

Simple, Robust Design

- **Simple designs keep capital and maintenance costs down**
 - Furling is a simple mechanism for power regulation at high wind speeds
- **More complexity may be necessary:**
 - for larger machines
 - to reach new markets



Source: Bergey Windpower



Source: NREL



Example System

- **On-Grid Southwest Windpower Skystream**

Skystream 3.7 220V	\$	5,380
33' Monopole tower	\$	1,530
Hinge plate & gin pole	\$	650
Shipping & Delivery	\$	1,060
Foundations	\$	1,300
Electrical	\$	1,050
Turbine Set-Up	\$	360
Misc. Costs	\$	300
Sales Tax (7.75%)	\$	901

Total \$12,531

Does not include permits!



Source: Southwest Windpower



CEC ERP Eligible Small Turbines

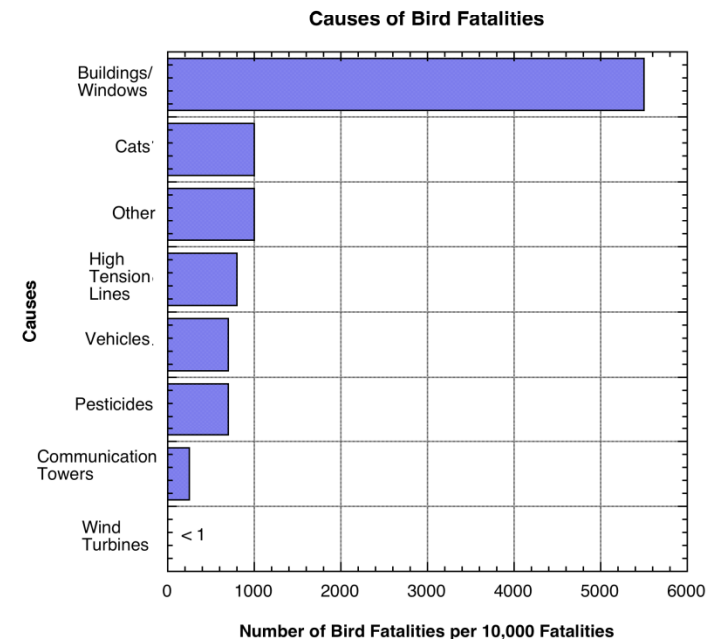
Source: CEC, http://www.consumerenergycenter.org/cgi-bin/eligible_smallwind.cgi

Manufacturer Name	Model	Description	Capacity (W)
Atlantic Orient Canada	AOC 15/50	50,000W Wind Turbine	50,000
Bergey Windpower	BWC 1500	1,500W Wind Turbine	1,500
Bergey Windpower	BWC EXCEL	10,000W Wind Turbine	10,000
Bergey Windpower	BWC XL.1	1,000W Wind Turbine	1,200
Cygnus Wind Systems	Wind Eagle 30	30,000W Wind Turbine	30,000
Endurance Wind Power, Inc.	S-250	4,250W Wind Turbine Generator System	4,250
Entegry Wind Systems	EW15	50,000W Wind Turbine	50,000
Fortis	Alize	12,000W Wind Turbine	10,000
Fortis	Montana	5,800W Wind Turbine	5,000
Fortis	Espada	800W Wind Turbine	750
Iskra Wind Turbine Manufacturers Ltd	AT5-1	Iskra AT5-1	5000
Point Power Systems	5.8 kW	5,800W Wind Turbine	5,000
Point Power Systems	0.8 kW	800W Wind Turbine	750
Point Power Systems	12 kW	12,000W Wind Turbine	10,000
Southwest Windpower	500	Whisper 500 Wind Turbine	3,000
Southwest Windpower	200	Whisper 200 Wind Turbine	1,000
Southwest Windpower	100	Whisper 100 Wind Turbine	900
Southwest Windpower	503	500W Windseeker Wind Turbine	500
Southwest Windpower	502	500W Windseeker Wind Turbine	500
Southwest Windpower	AIR403	400W Wind Turbine	472
Southwest Windpower	Skystream 3.7	1,800W (2400W peak) Direct Grid-Connect Turbine	1,800
Synergy Power Corporation	SLG/S300	Survivor 30,000W Wind Turbine	30,000
Wind Turbine Industries	23-10	10,000W Jacobs 23-10 Wind Turbine	10,000
Wind Turbine Industries	31-20	20,000W Jacobs 31-20 Wind Turbine	20,000



Avian Mortality

- On a global scale, wind turbines have a negligible effect on bird fatalities
- On a local scale, problems may occur if wind plants are located in or near bird habitats or migratory pathways
- Altamont Pass
 - The location of the world's first wind plants
 - Development occurred before the effect on birds was recognized
 - Wind plants have been in violation of the:
 - Bald and Golden Eagle Protection Act
 - Migratory Bird Treaty Act
 - And others...
- Bat mortality has emerged as a new problem in recent years

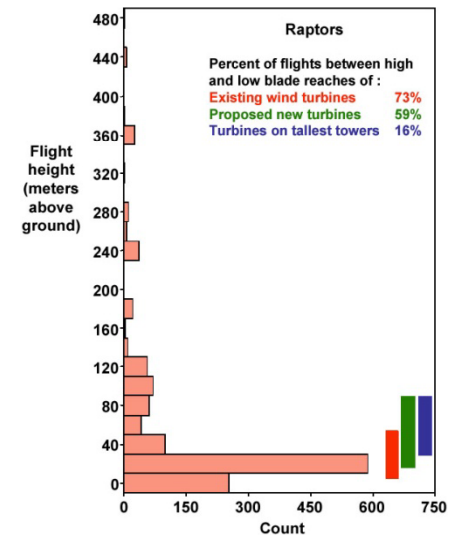
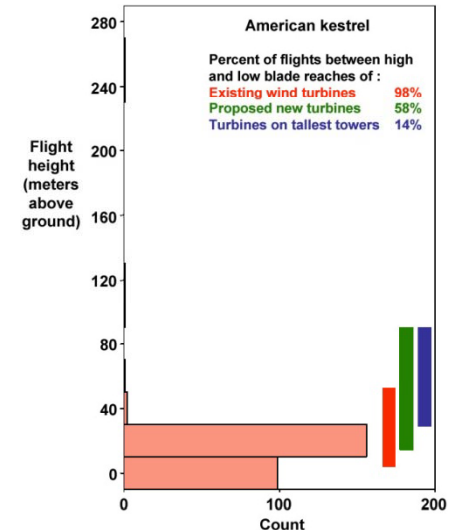


Data Sources: Erickson et al, 2002, Summary of Anthropogenic Causes of Bird Mortality



Preventing Avian Mortality

- An extremely complex problem with no easy solutions.
- A careful site evaluation prior to development is critical.
- Bird behavior varies with species and site.
- Visual and audio deterrents have not proven to be successful.
- Many assumptions can turn out wrong:
 - “Lattice towers are problems because of perching”
 - Approximately same number of kills with tubular towers
 - Most perching is on non-operating turbines
 - “Remove their prey”
 - Ground squirrel eradication resulted in pocket gopher explosion
- Taller turbines may be beneficial.
- Turbine layout and placement within a site may have an effect.
- Avoid creating habitat for prey near turbines.
- Altamont recently initiated seasonal shutdowns.



Source: S. Smallwood





Reliance on fossil fuels hurts birds, plain and simple. Pollution, destruction of habitat from mining, and potentially disastrous global climate change are all significant stresses on birds and other wildlife. Wind power, when sited properly after adequate study, is a better option. Modern wind projects undergo a significant amount of review and study for a variety of factors before construction begins.

- David J. Miller, Executive Director, Audubon New York
<http://ny.audubon.org/news/060711.htm>