

Wind Technologies for Consumers

March 13, 2007



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NREL/NWTC

Outline

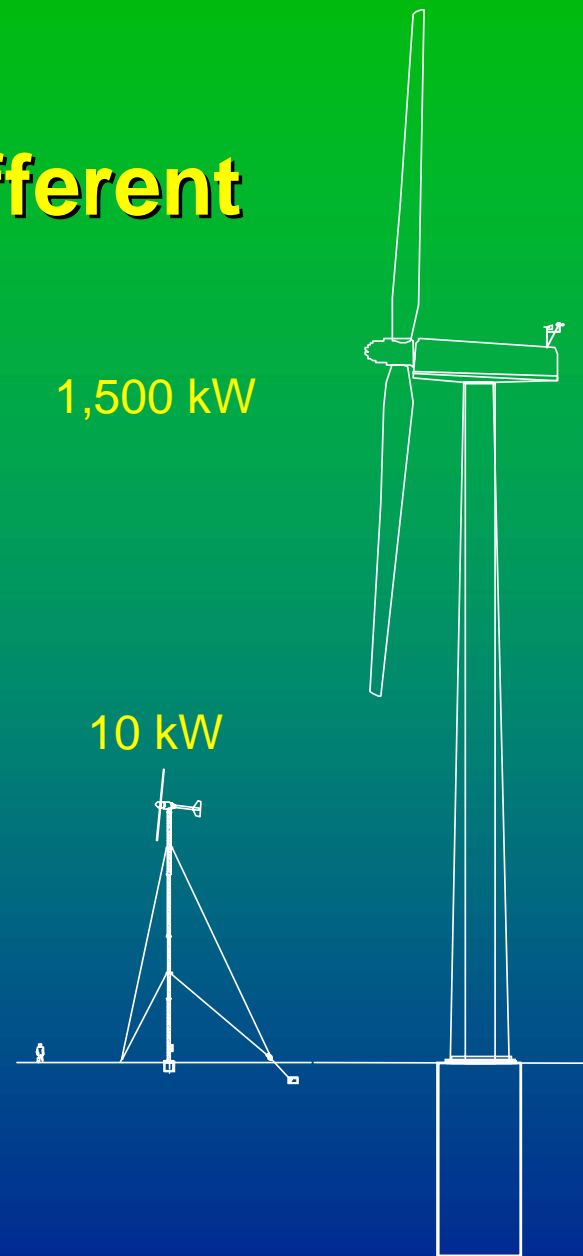
- Overview of Small Wind Turbine technology
- Steps to implement a small wind project
- Overview of commercial small wind turbines
- US policies for small wind turbines – www.dsireusa.org
- More information

Calculation of Wind Power

- Power in the wind = $\frac{1}{2} \rho A V^3$
 - Effect of wind speed, V
 - Effect of rotor diameter on swept area, A
 - Effect of elevation and temperature on air density, ρ

Small Wind Turbines Are Different

- Utility-Scale Wind Power
600 - 1,800 kW wind turbines
 - Installed on wind farms, 10 – 300 MW
 - Professional maintenance crews
 - 13 mph (6 m/s) average wind speed
- Small Wind Power
300 W - 250 kW wind turbines
 - Installed at individual homes, farms, businesses, schools, etc.
 - On the “customer side” of the meter, or off the utility grid entirely
 - High reliability, low maintenance
 - 9 mph (4 m/s) average wind speed



Small Wind Turbines

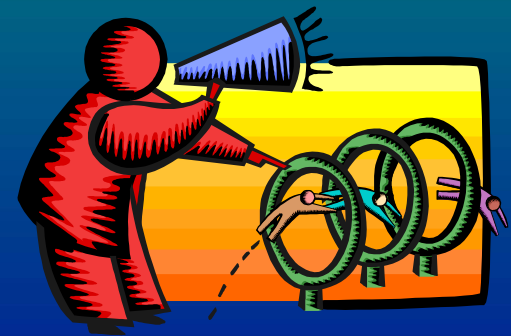
- **Configuration:** 2 or 3 blades aimed into the wind by the tail
- **Blades:** Fiber-reinforced plastics
- **Over-Speed Protection:** Furling (rotor turns out of the wind), no brakes
- **Generator:** Direct-drive, permanent magnet alternator (no brushes), 3-phase AC, variable-speed operation
- **Controller:** Electronic device that delivers
 - DC power for charging batteries
 - AC power for utility interconnection
- **Result:**
 - Simple, rugged design
 - Only 2–4 moving parts
 - Little regular maintenance required



Bergey EXCEL, 10 kW

Steps to Implement a Small Wind Project

1. Assess your electricity consumption, cost, and utility tariff
2. Wind resource & micro-siting
3. Select turbine size (model) and tower height
4. Incentives & economics
5. Zoning (including neighbor notification)
6. Utility interconnection agreement
7. Building permit
8. Order turbine and tower
9. Installation
10. Commissioning

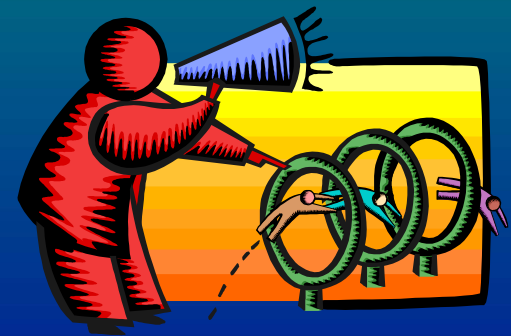


Two Types of Electric Tariffs

- “Energy Tariff”
 - Typical for residential service
 - Fixed monthly service charge, \$5-15/mo, plus a kWh charge
- “Demand Tariff”
 - Typical for commercial and service to larger farms
 - Fixed monthly service charge, \$5-15/mo, plus a kWh charge, plus a demand charge, per kW, based on peak demand during the billing period

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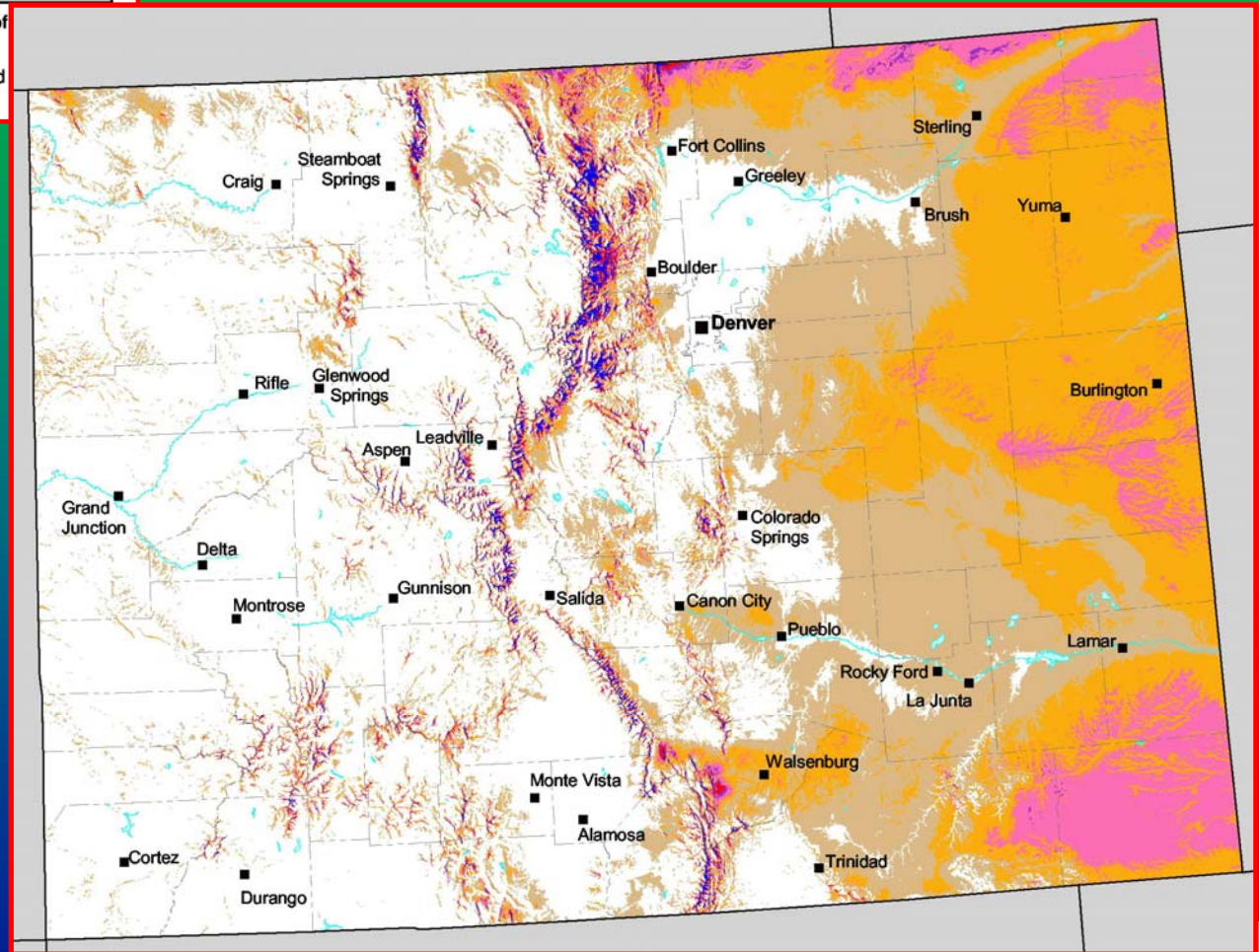
Colorado Wind Resource Map

Small Wind Turbine Productivity Estimates*

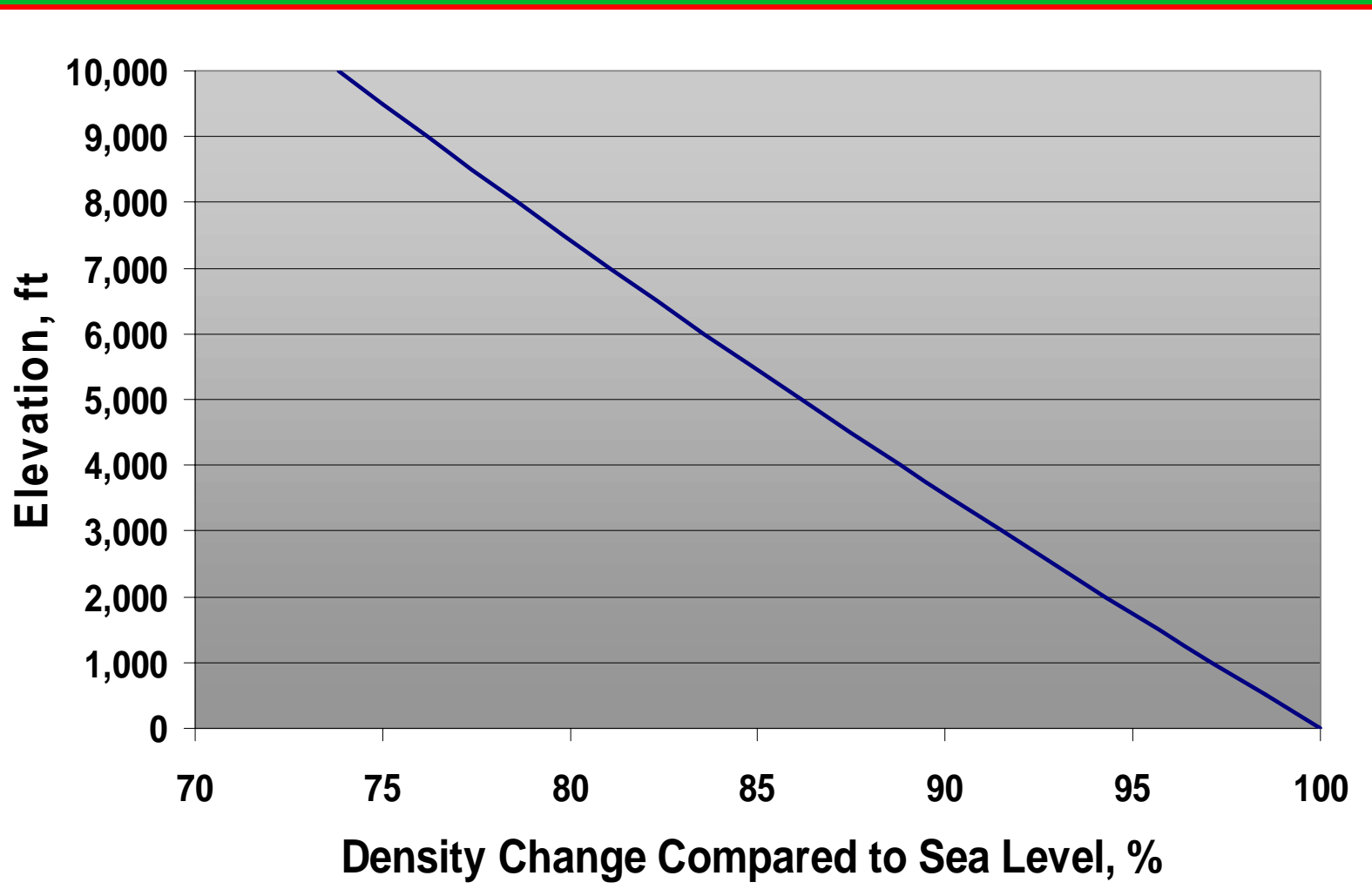
Wind Power Class	Productivity per m ² of swept area** (kWh/year)	Wind Power Density at 33 ft (10 m) (W/m ²)	Wind Speed at 33 ft (10 m) (mph)	Wind Speed at 33 ft (10 m) (m/s)
1	< 350	<100	< 9.8	< 4.4
2	350 - 500	100 - 150	9.8 - 11.5	4.4 - 5.1
3	500 - 610	150 - 200	11.5 - 12.5	5.1 - 5.6
4	610 - 690	200 - 250	12.5 - 13.4	5.6 - 6.0
5	690 - 770	250 - 300	13.4 - 14.3	6.0 - 6.4
6	770 - 880	300 - 400	14.3 - 15.7	6.4 - 7.0
7	880 -1170	400 -1000	15.7 - 21.1	7.0 - 9.4

* Estimates are based on different models and sizes of assuming a tower height of 80 ft (24 m).

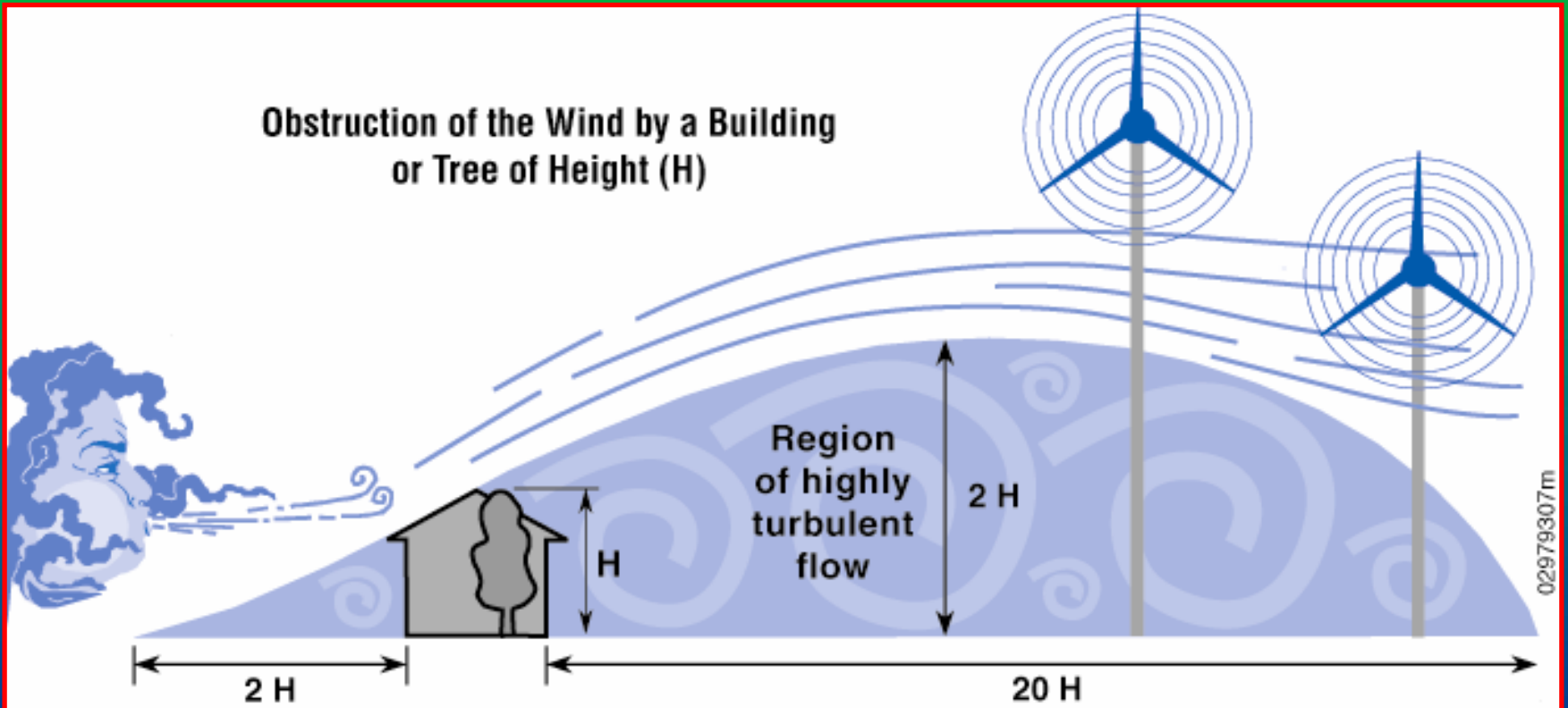
** For systems of different sizes, multiply the estimated the total swept area of the turbine.



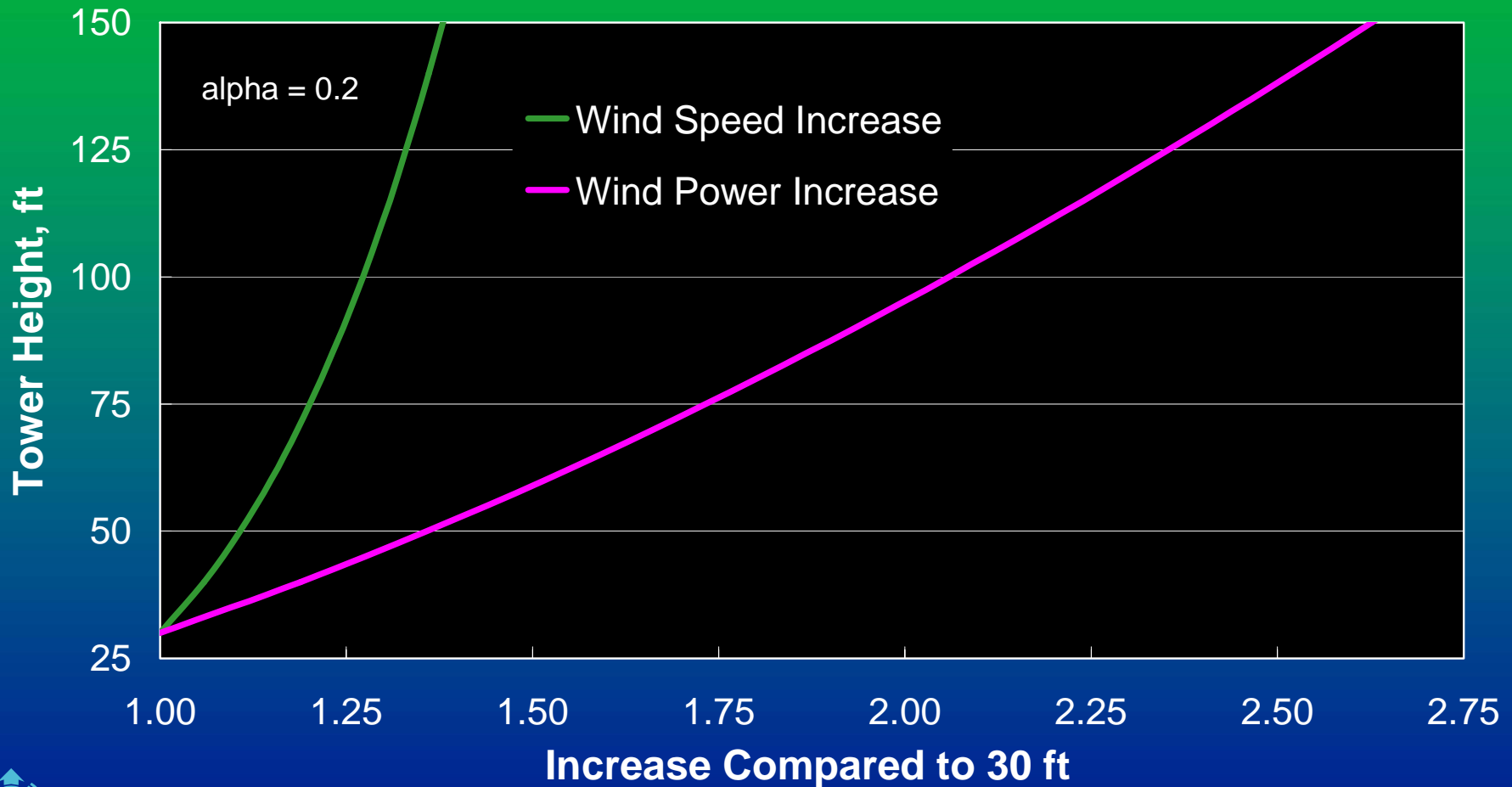
Air Density Changes with Elevation



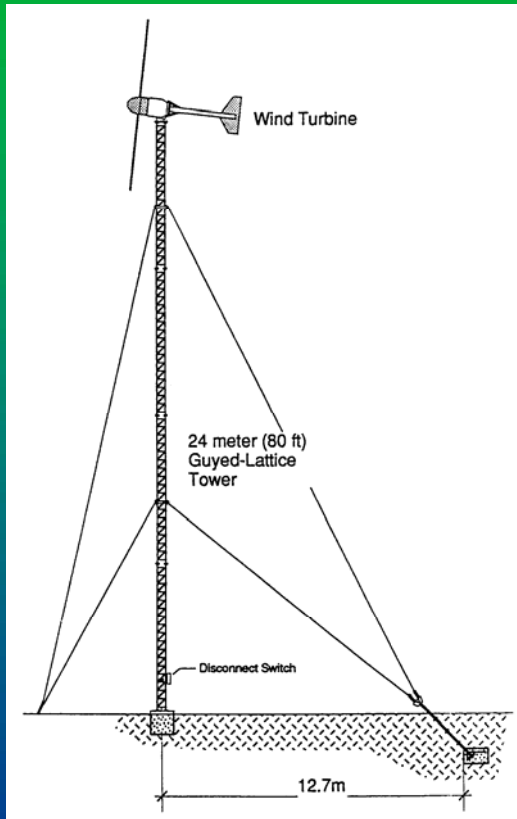
Importance of “Micro-Siting”



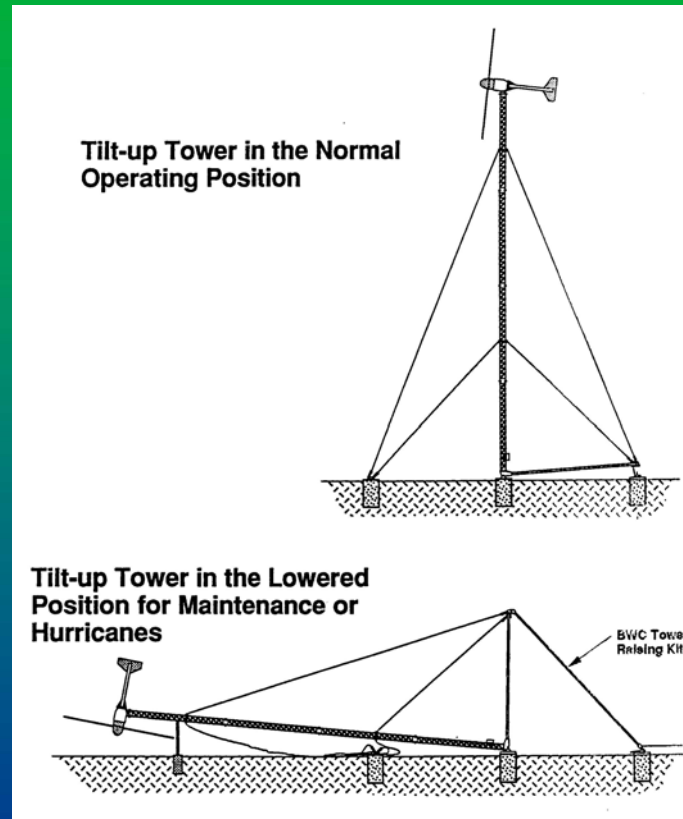
Wind Speed & Power Increase with Height Above the Ground



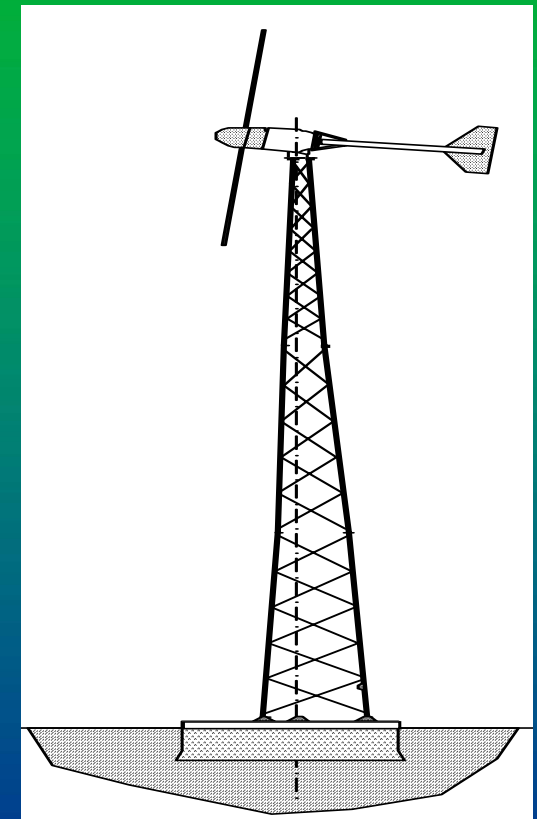
Small Wind Turbine Towers



Guyed Tower



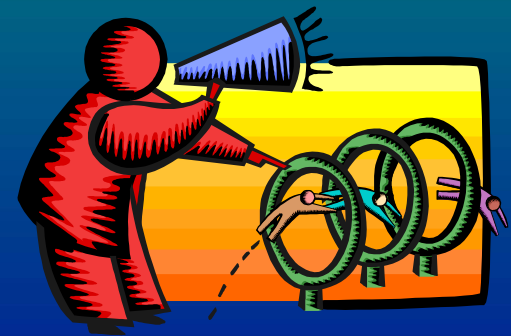
Tilt-Up Tower



Self-Supporting
Tower

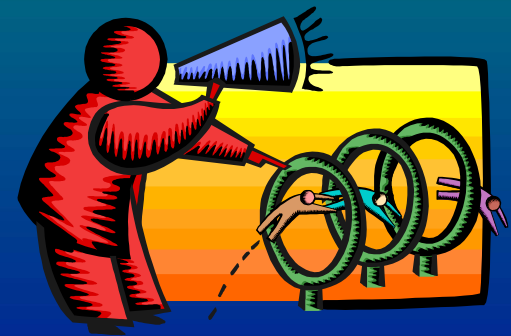
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State Incentives

www.dsireusa.org

- Colorado
 - Annualized net metering – Xcel
 - Future legislation?
- Renewable energy credits?

Federal Small Wind Incentives

- USDA Renewable Energy Systems and Energy Efficiency Improvements Program (Section 9006) - 25% grants for farms and rural businesses (not for residential systems)
- 5-Year Depreciation For Businesses - Modified Accelerated Cost-Recovery System (MACRS)
- Future Federal Investment Tax Credit?

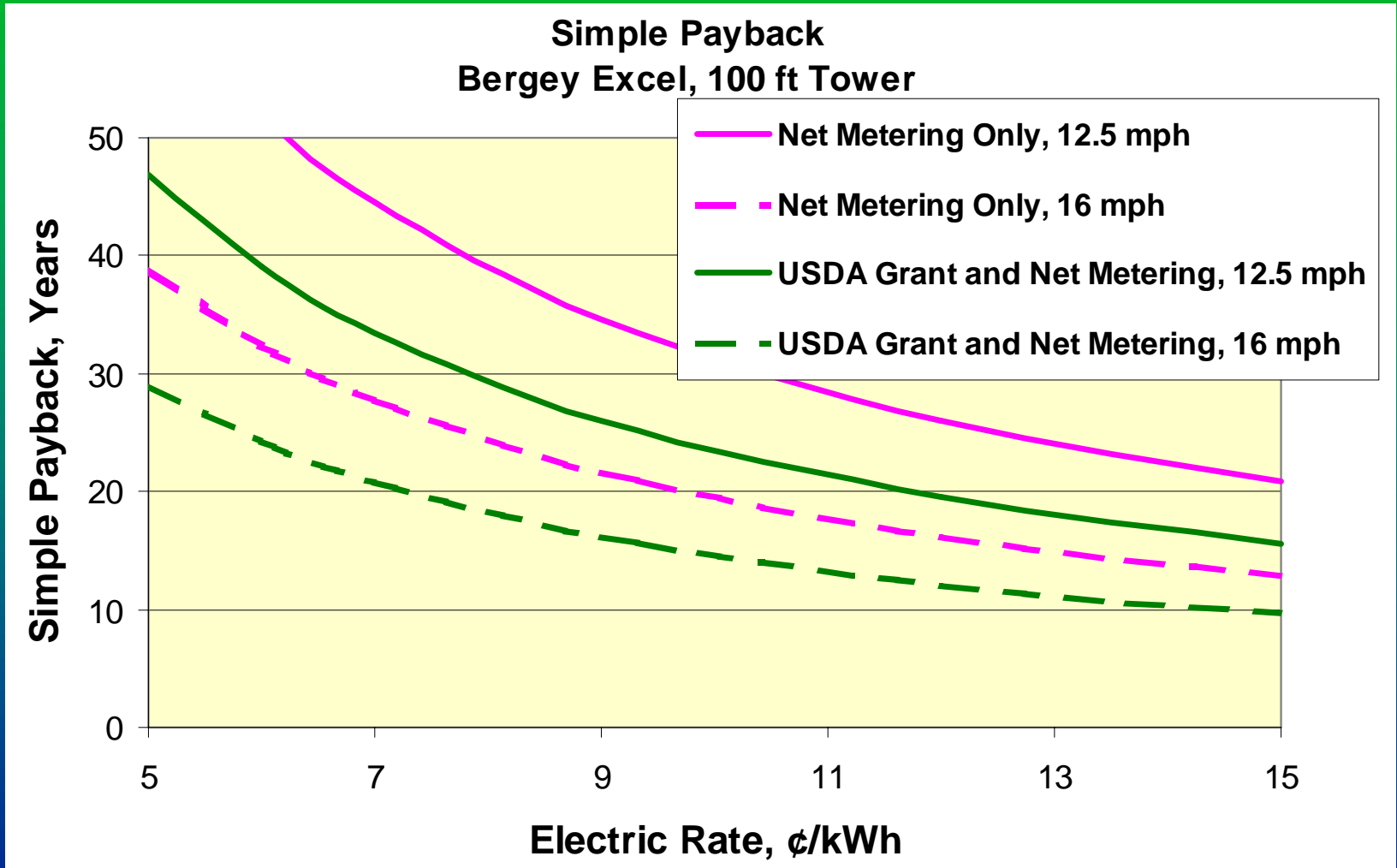
Economics of a Wind Project

- “Simple Payback” is an easy way to measure the economic merit of a wind turbine project:

$$\frac{\text{(Installed cost, \$)}}{\text{(kWh/y X Price of Electricity, \$/kWh)}} \\ \text{(years)}$$

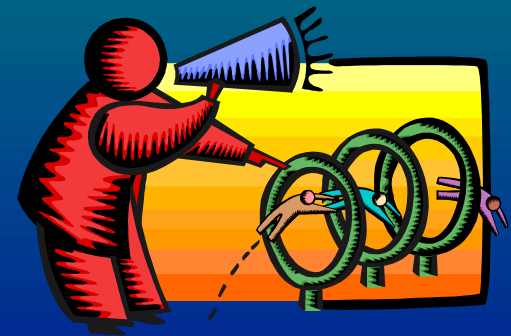
- Installed cost = Turbine System Cost + Balance of Station (BOS) cost
 - BOS vary by location
 - Foundation, rebar, equipment & manpower
 - trenching, conduit and wire to get electricity to the electrical meter
 - Permit, zoning, insurance, licensed engineer costs
 - other

Small Wind Economics



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Zoning Scenarios

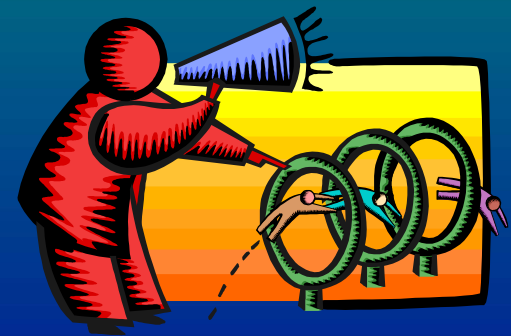
1. No Zoning – Your local jurisdiction may not have exercised their authority to regulate land use.

For Jurisdictions With Zoning:

2. Wind turbine tower is allowed – common in agricultural zones?
3. Structures above 35 ft are not allowed – common in residential zones
 - Obtain a “Variance” or a “Special Use Permit”
(permission to violate the zoning code on one property)
 - Hearing process can cost thousands of dollars and take several months
4. Work with the local jurisdiction to pass a small wind zoning ordinance (broad application to many properties)

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Interconnection Agreement

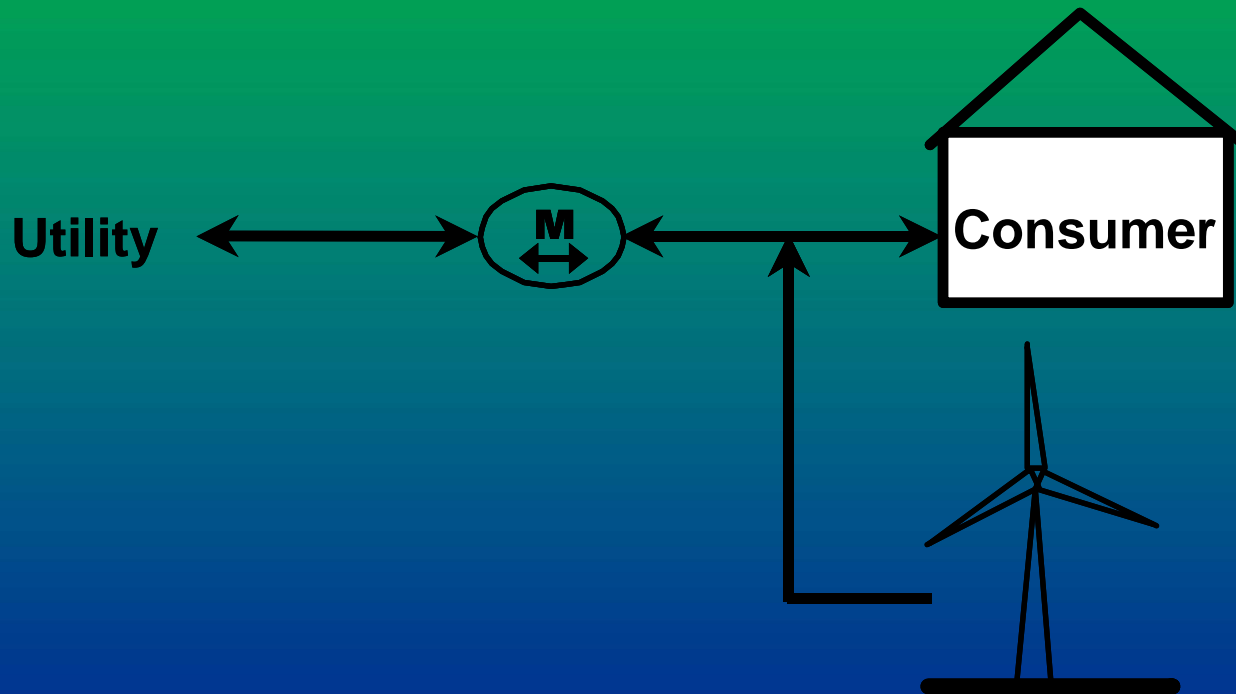
- Contact your utility before buying a wind turbine to learn about the their agreement
- Some utilities use a simple form for interconnection of small turbines
- Compliance with accepted standards to ensure safety and acceptable power quality:
 - IEEE 1547 and UL 1741
 - National Electric Code
- Liability Insurance
 - Standard homeowners liability coverage should be adequate for small wind turbines (\$300,000 typical)
 - Requirements for \$1M coverage will be cost prohibitive
 - No known liability claims



Meter Configuration For Net Metering

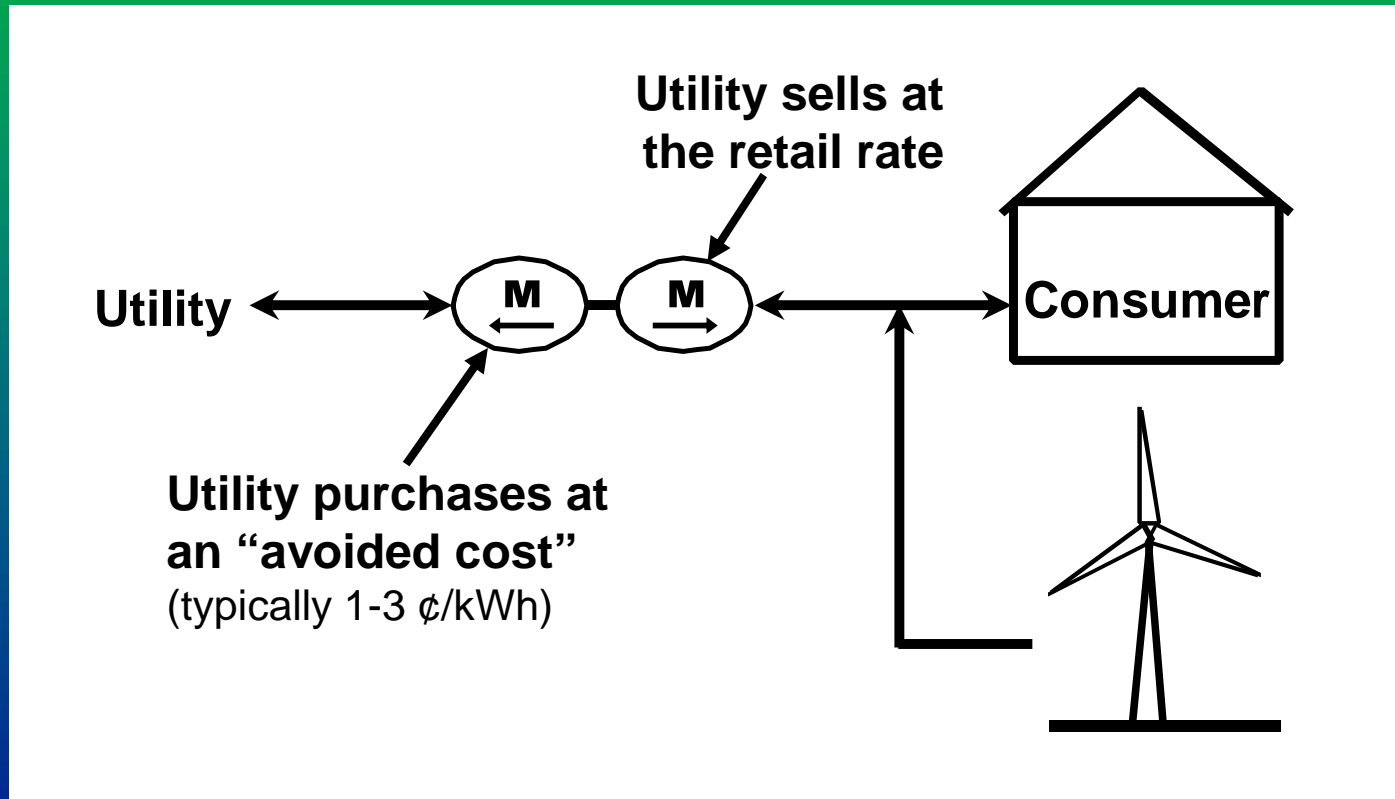
Cumulative net energy is recorded.

The account is settled either monthly or annually.



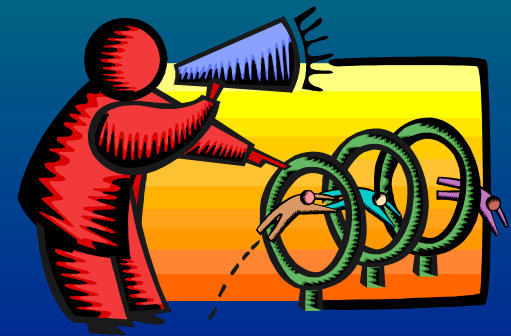
Meter Configuration For Net Billing

Net energy is recorded instantaneously as either a purchase or a sale.



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Types of Permits

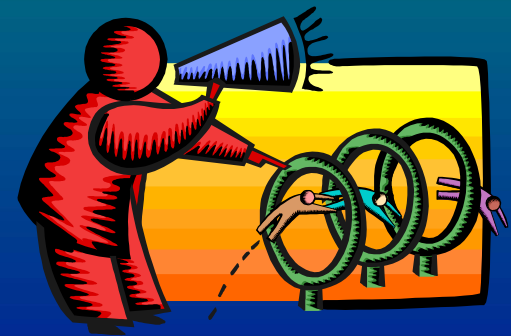
- Zoning controls *whether* you can install a wind turbine
- Permits control *how* you install a wind turbine
- Two primary types of permits:
 - Building permit (structural safety)
 - Electrical permit (electrical safety)
- Permitting is done locally
- Every jurisdiction is unique
- Investigate early in the process
 - Talk to the local authorities
 - Talk to local contractors

Permit Process

- Fees varies by jurisdiction:
 - ~ \$50 up to \$6,000 (in California)
- Submittals:
 - Site plan
 - Structural analysis on foundation and tower, may require either wet stamp or dry stamp
 - Electrical one-line diagram, UL label required for grid-connected device (at least)
- Inspections

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Southwest Windpower

Flagstaff, Arizona

www.windenergy.com

Skystream 1.8 kW

\$5,400 + tower as of 2/07

Estimated 3,600 kWh/year



AIR-X 300 w



Whisper 100 900 w



Whisper 200 1000 w



Whisper 400 3 kW

Key Implementation Details

Removable Hatchcover
& Inverter Assembly

Slotless Edge-
Wound Stator

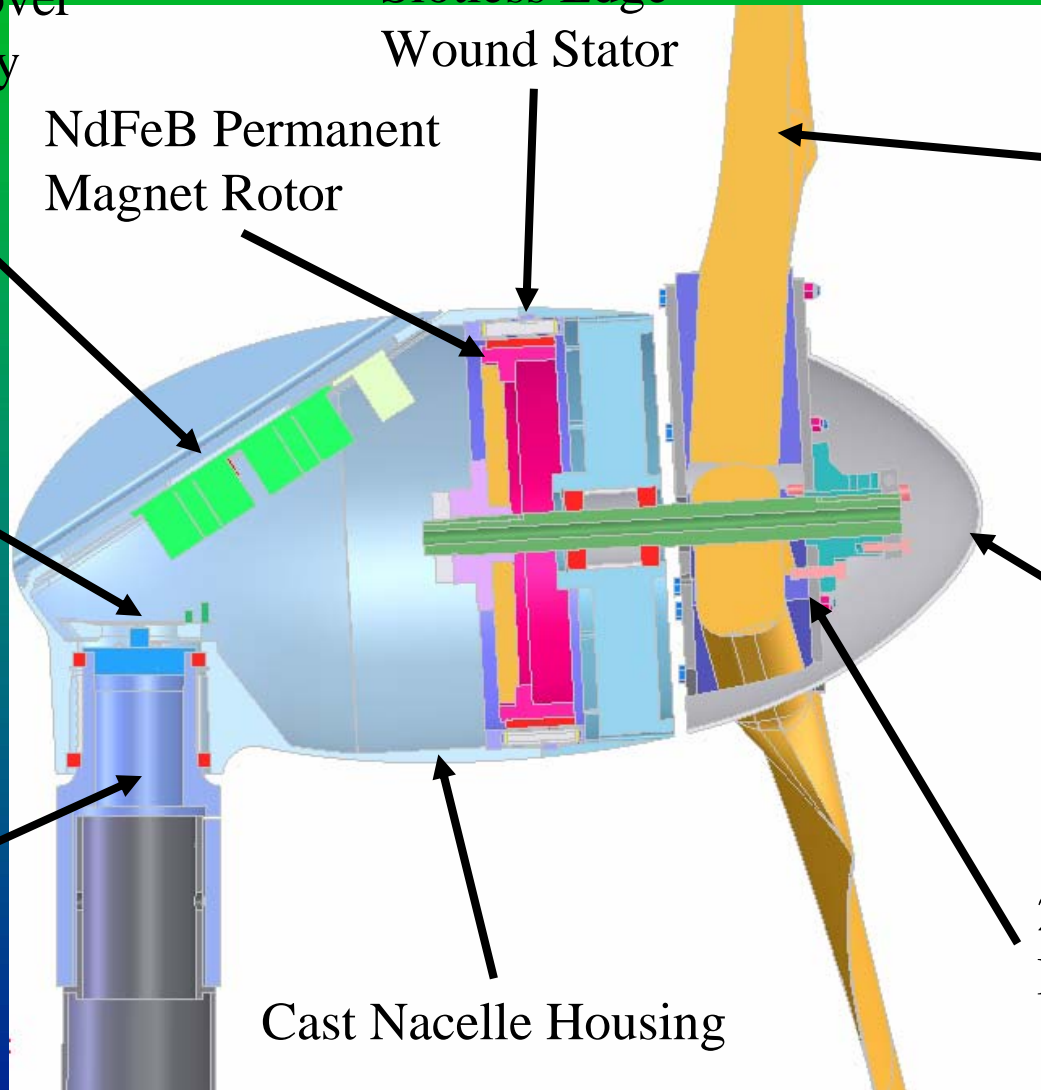
NdFeB Permanent
Magnet Rotor

S822/S823
GRP Blades

PCB-Based
Sliprings

GRP
Nosecone

2-Plate
Blade Hub



Cast Nacelle Housing

Clamp-on
Yaw Assembly



Windward Endurance Wind Turbine

5.5 m diameter; 5 kW; constant speed - 200 rpm

www.windwardengineering.com

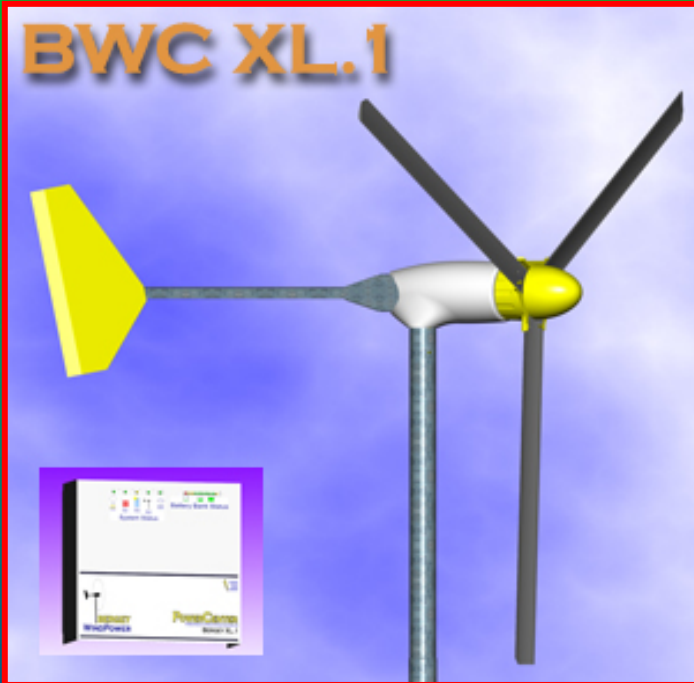
\$22,500 + tower as of 2/07
Estimated kWh 7,700/year



Bergey Windpower

www.bergey.com Norman, OK

1 kW



BWC Excel

10 kW

\$2,150 + 104' tube tower \$1,850 (3/05)

Estimated 1,400 kWh/year

\$24,750 + 100' guyed tower \$7,800 (3/05)

Estimated 11,700 kWh/year



Wind Turbine Industries, Inc. Prior Lake, MN

Jacobs
29/20
20 kW



\$35,267 + 100' guyed tower \$7,800 (3/05)
Estimated 11,700 kWh per year



Entegritty Wind

www.entegrittywind.com

EW15

60 kW



\$125,000 – 80' tower (3/05)
Estimated 96,900 kWh per year



Vestas V-15 and EMS E-15

www.energymms.com



MODEL E15
WIND TURBINE SYSTEM

\$67,000 refurbished E15 (3/05)



Northern Power Systems

Northwind 100
NW 100/19
100 kW

www.northernpower.com

Waitsfield, VT

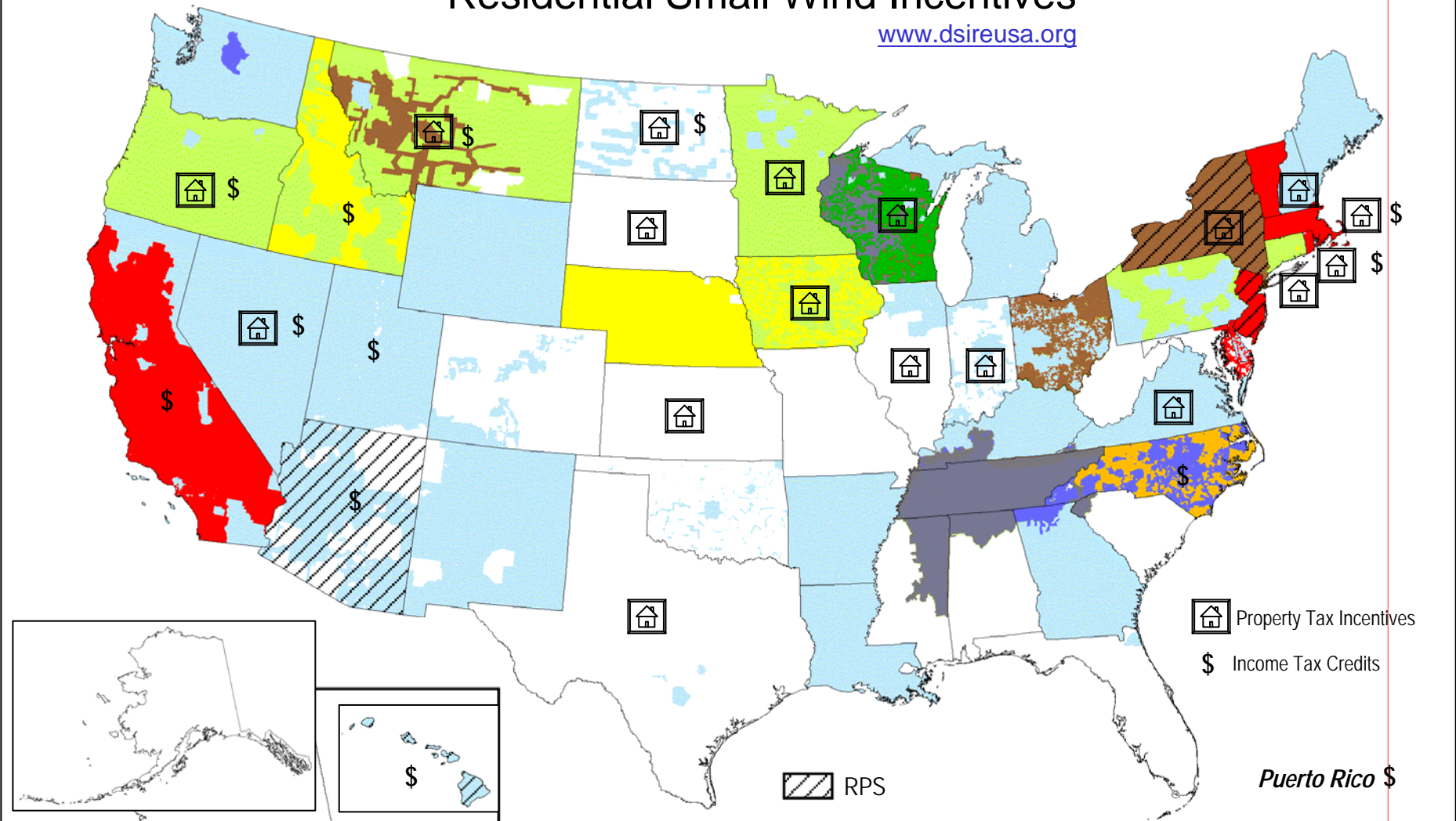


\$265,000 + refurbished 32m tower (3/05)
Estimated 193,000 kWh per year



Residential Small Wind Incentives

www.dsireusa.org



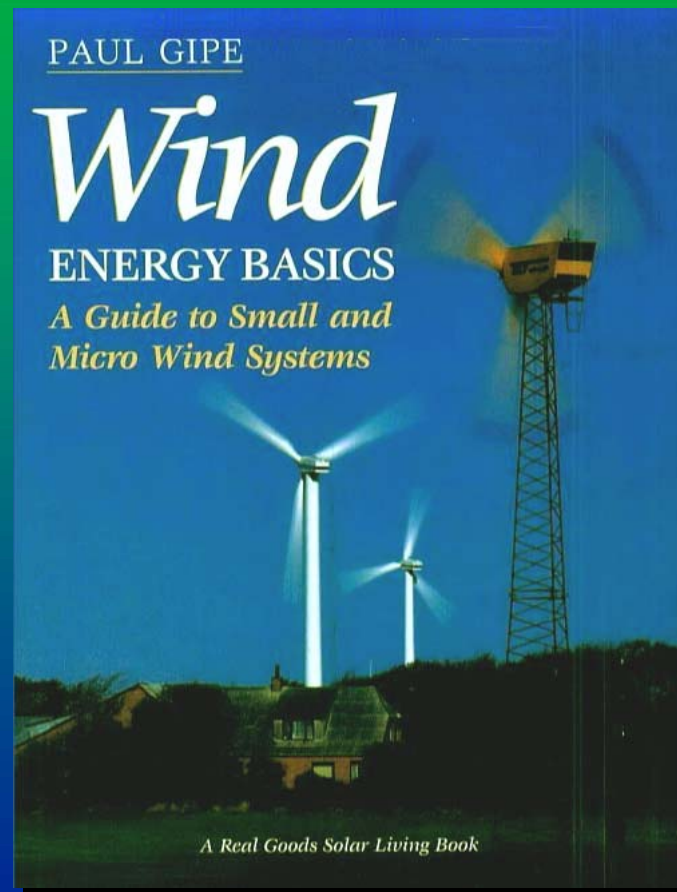
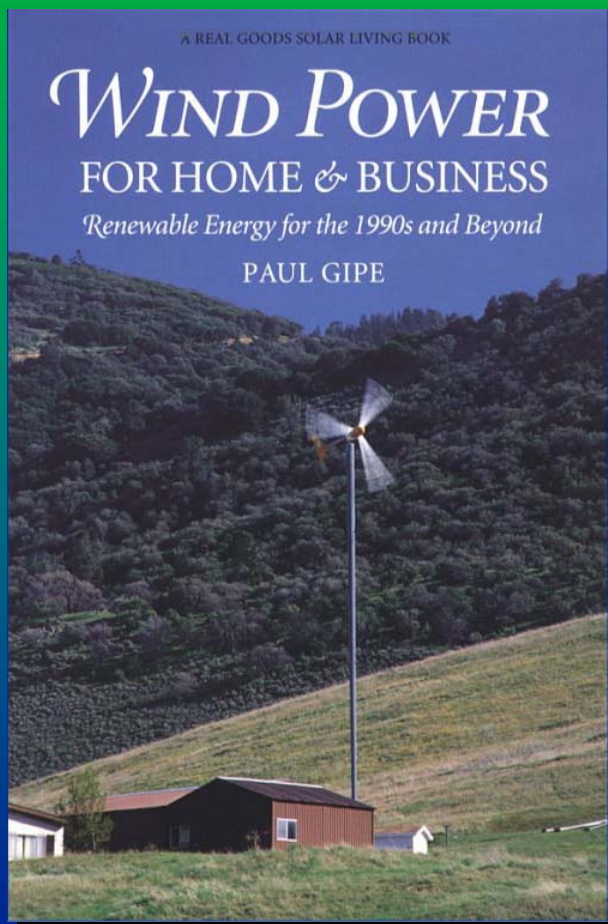
BUYDOWNS	PRODUCTIVITY INCENTIVES	MINOR INCENTIVES
Buydown & Net Metering	Productivity Incentives & Loans	Loans
Buydown, Net Metering, & Loans	Net Metering, Loans & Prod. Incentives	Net Metering & Loans*
	Productivity Incentives	Net Metering
	Net Metering & Prod. Incentives	

*In Minnesota, loans apply only to farmers.

Books by Paul Gipe

Available from Chelsea Green Publishing Co.

www.chelseagreen.com



More information

National Renewable Energy
Laboratory:
http://www.windpoweringamerica.gov/small_wind.html

American Wind Energy
Association
www.awea.org
small wind pages

Small Wind Electric Systems

A U.S. Consumer's Guide



U.S. Department of Energy

