Small Wind Turbine Selection

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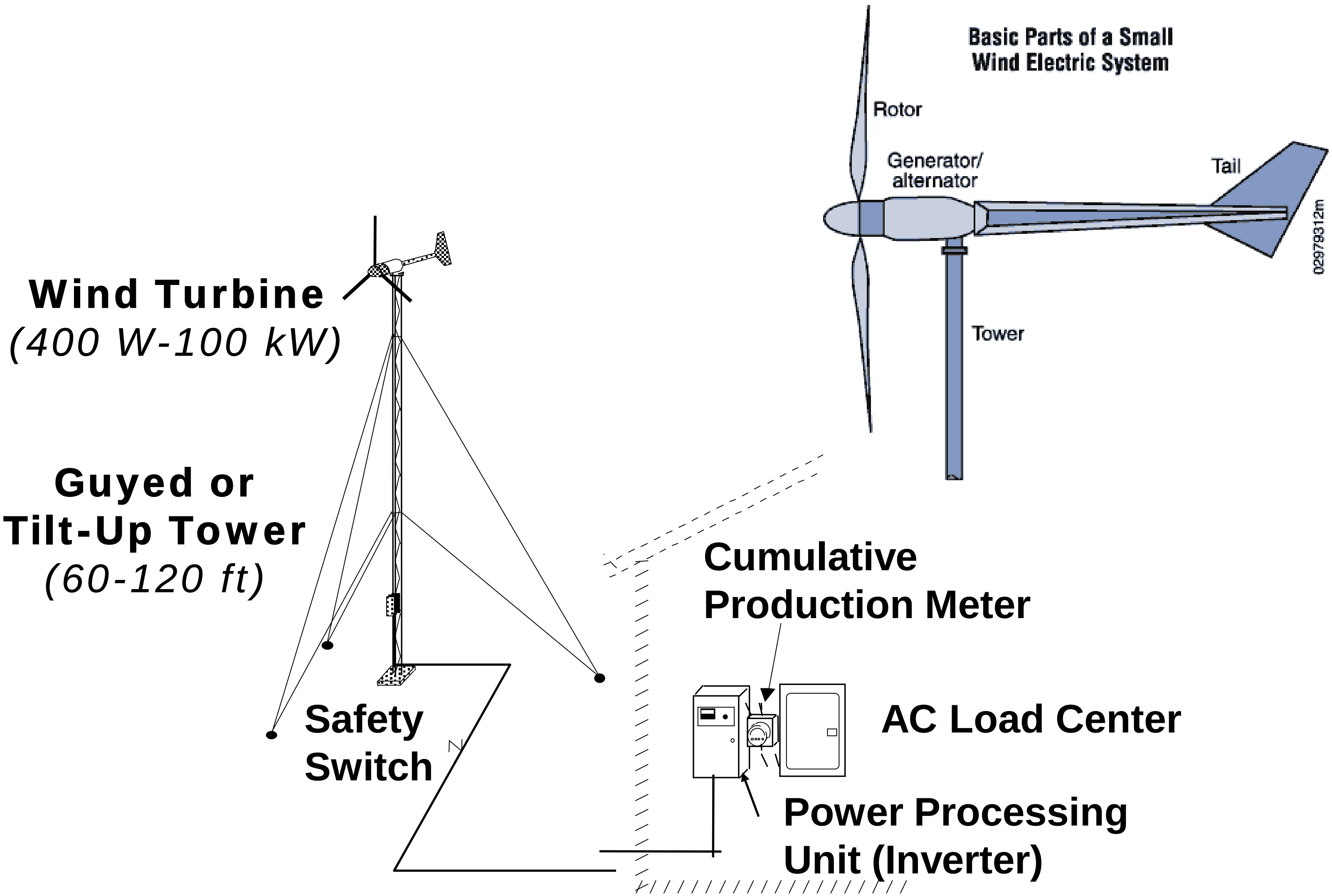
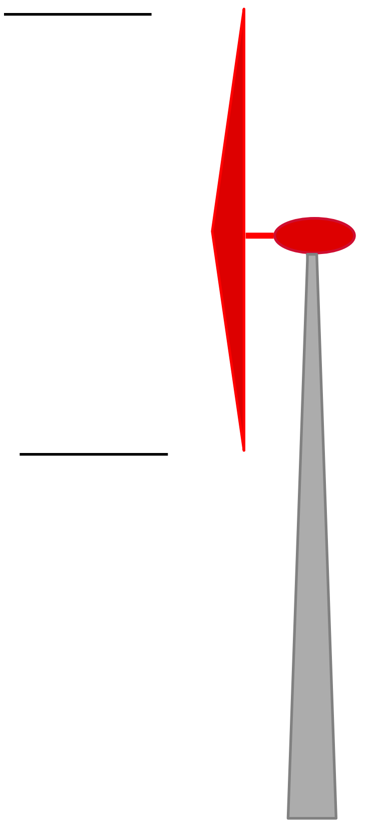
Homes, Business, Farm, Schools, and Public Buildings

How Small Wind Turbines Work



$$P = \frac{1}{2} \cdot c_p \cdot \rho \cdot v^3 \cdot A$$



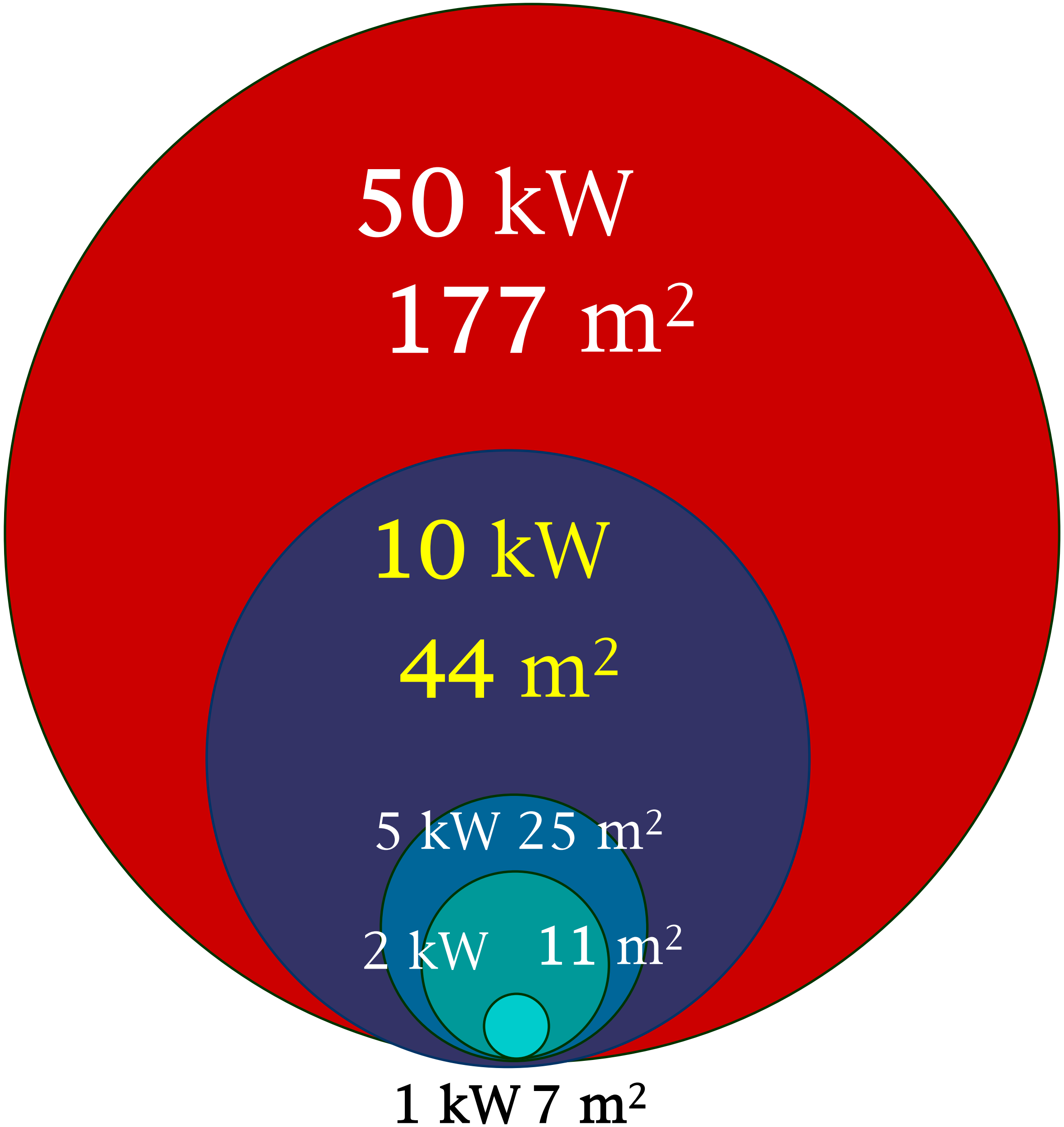
P = power (watts)

c_p = coefficient of performance

ρ = density of air (kg/m^3)

v = wind speed (m/s)

A = rotor swept area (m^2)


50 kW
177 m²
10 kW
44 m²
5 kW 25 m²
2 kW
11 m²
1 kW 7 m²

WIND TURBINES

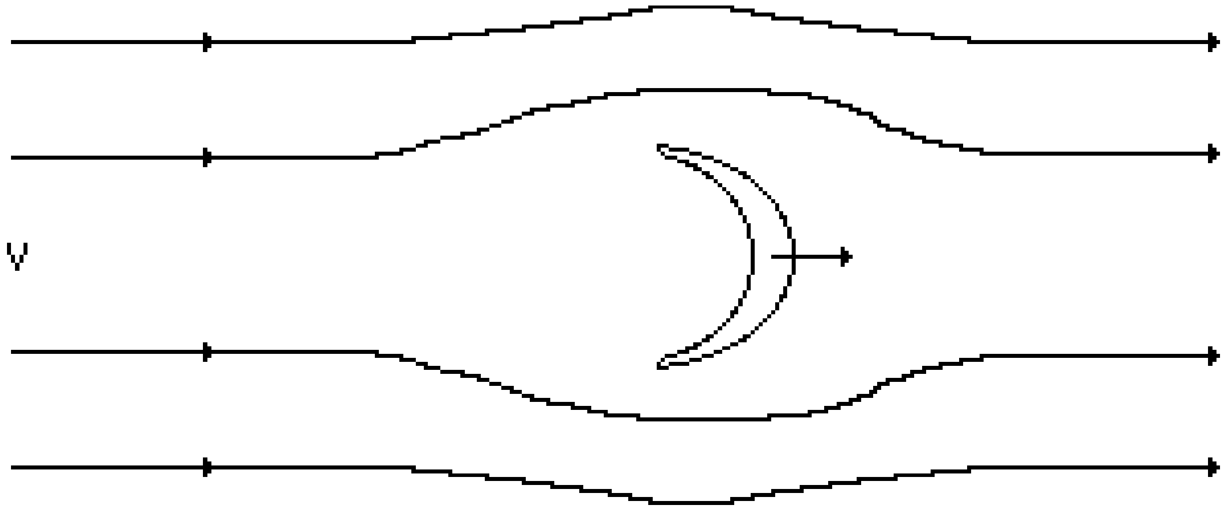
DRAG AND LIFT

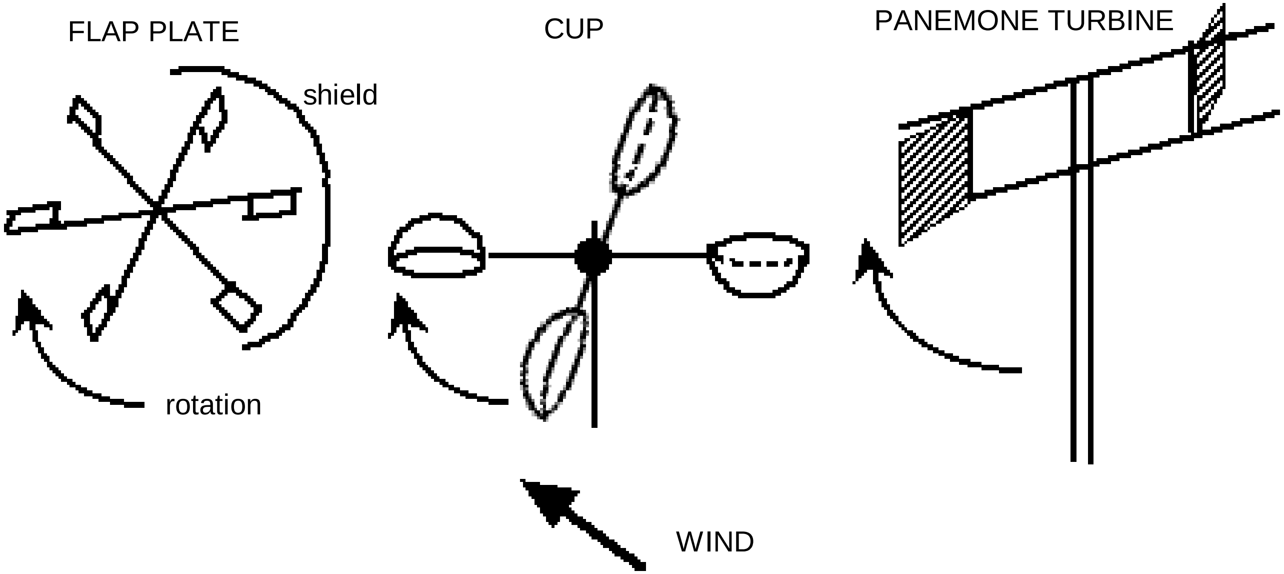
AERODYNAMICS

POWER CURVE

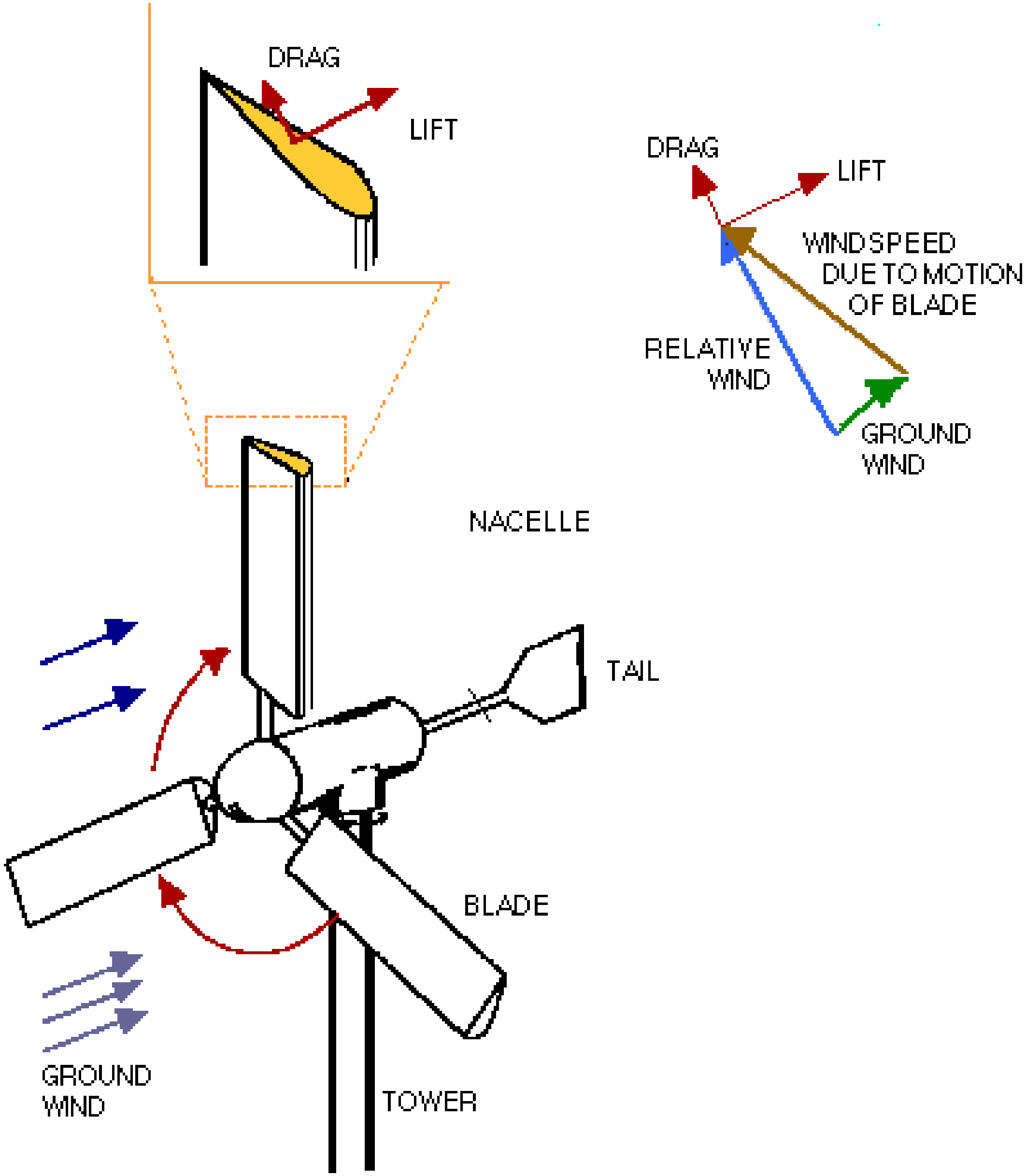
CAPACITY FACTOR

DRAG

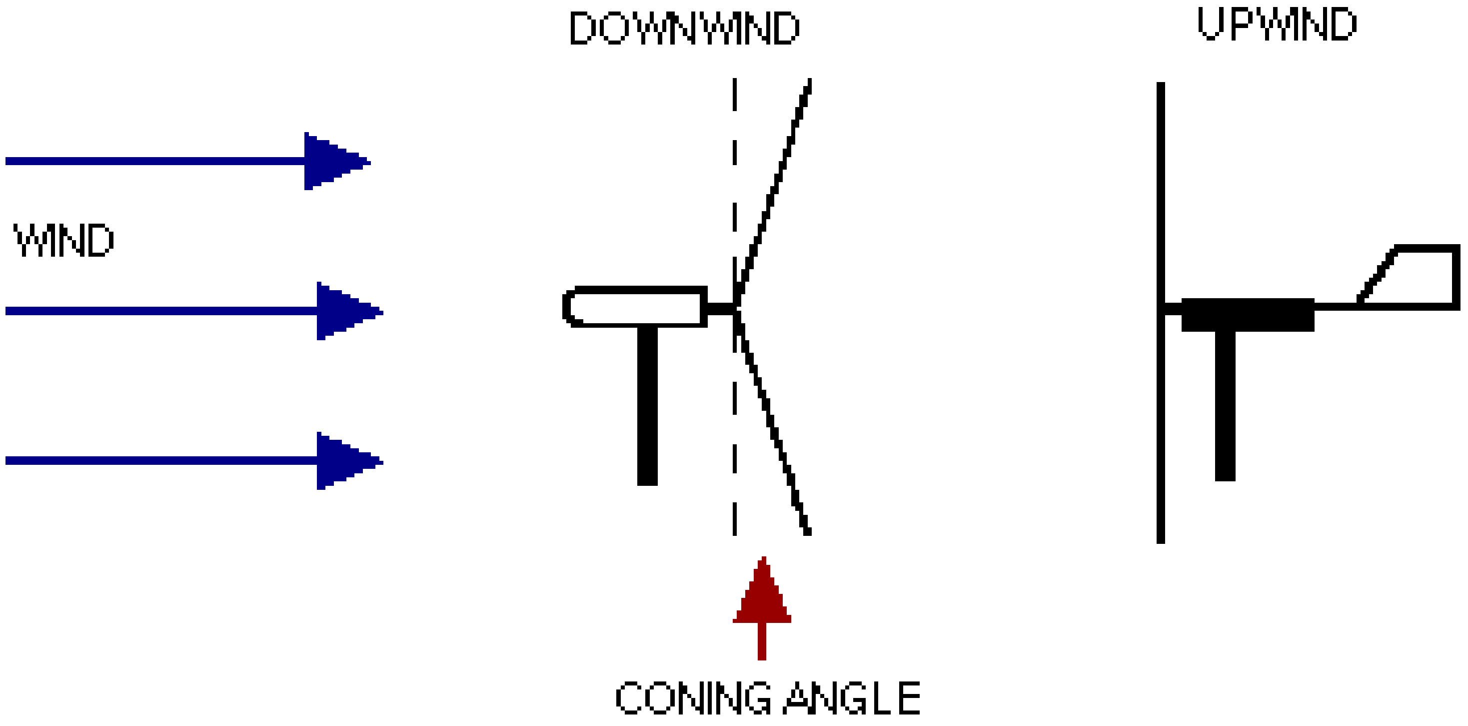




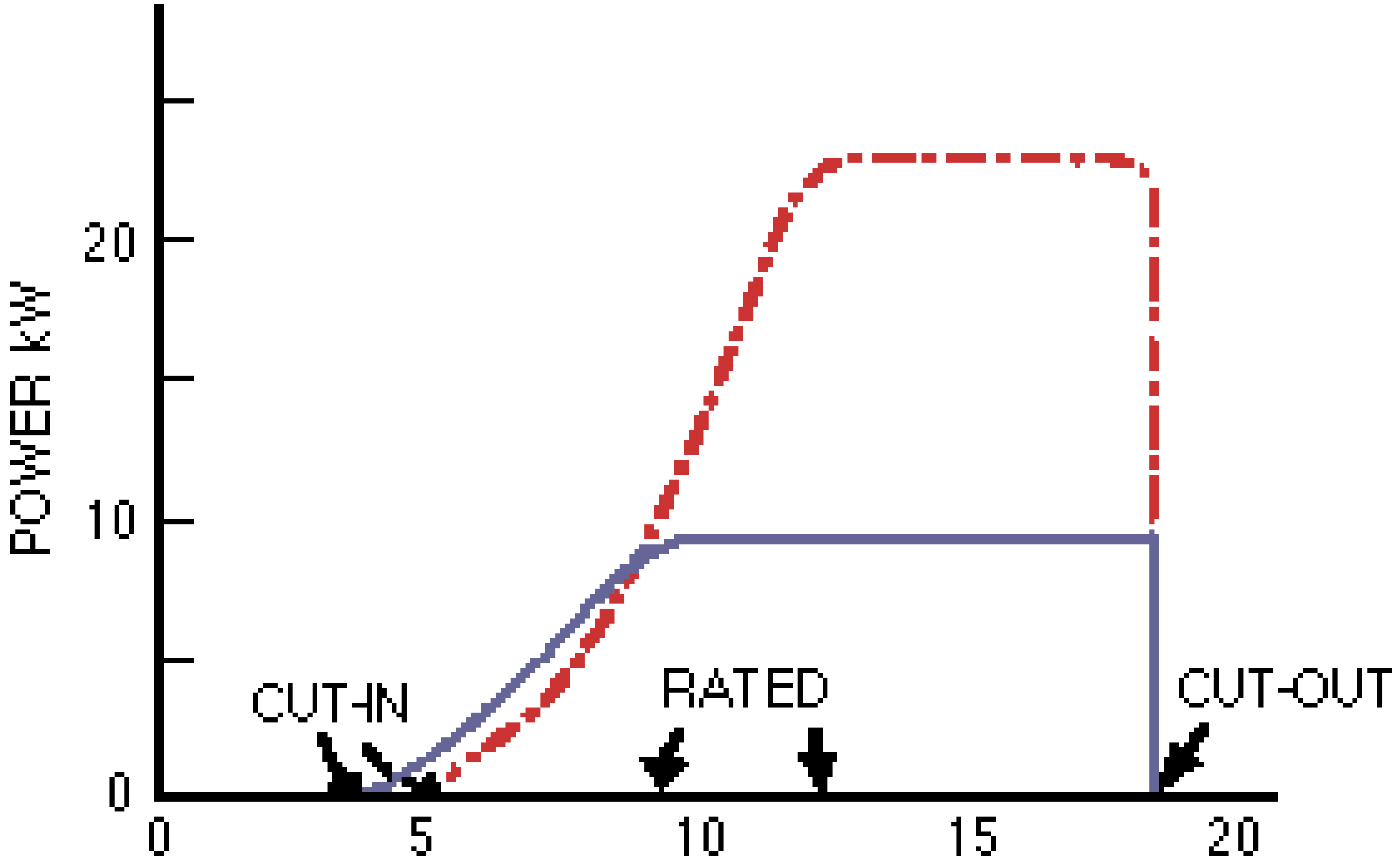
Drag Type Machine

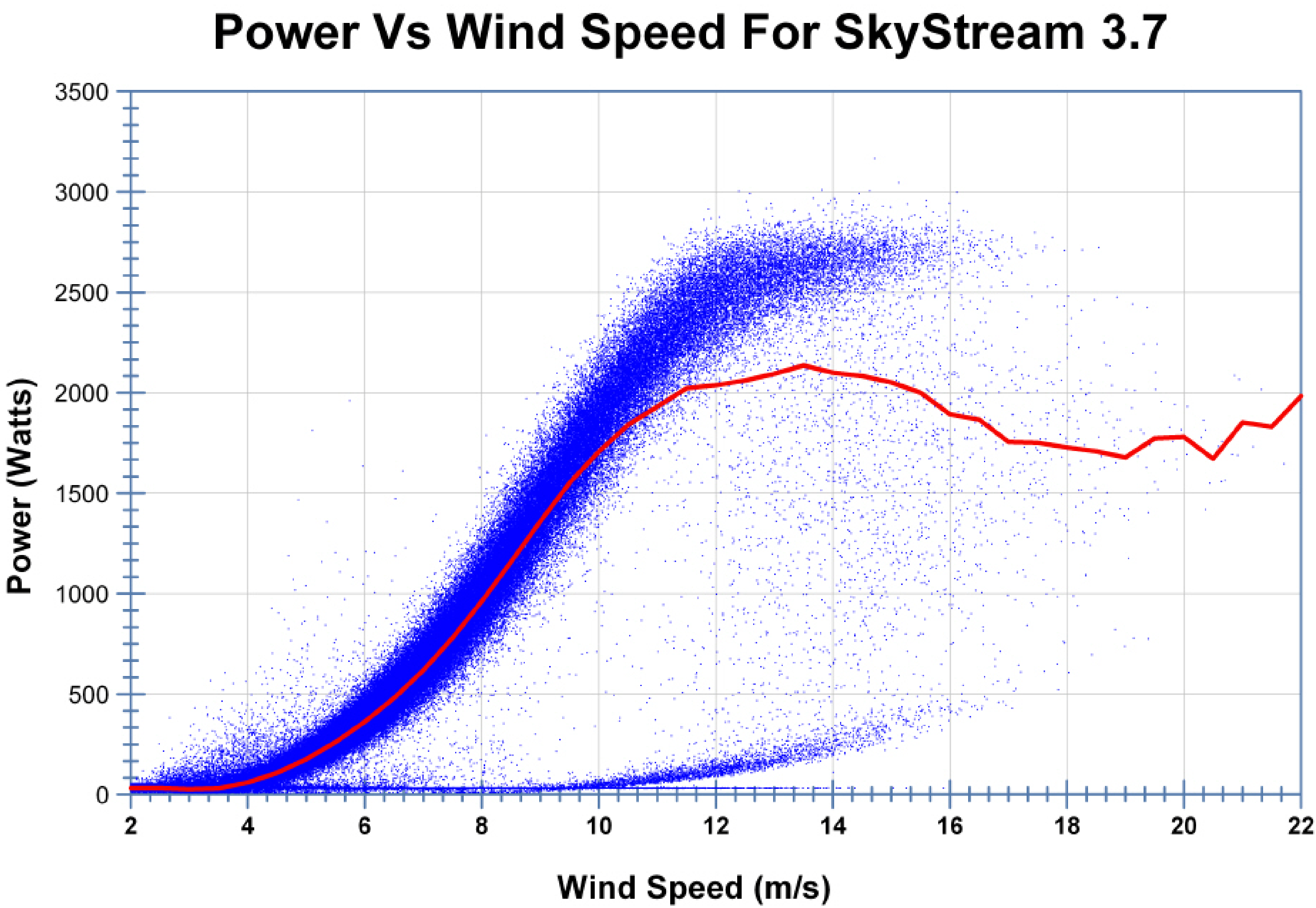

DRAG
LIFT
DRAG
LIFT
WINDSPEED
DUE TO MOTION
OF BLADE
RELATIVE
WIND
GROUND
WIND
NACELLE
TAIL
BLADE
GROUND
WIND
TOWER

Lift Type Machine


DOWNWIND
UPWIND
WIND
CONING ANGLE

POWER CURVE





Power Vs Wind Speed For SkyStream 3.7
Power (Watts)
3500
3000
2500
2000
1500
1000
500
0
2
4
6
8
10
12
14
16
18
20
22
Wind Speed (m/s)

Capacity Factor

$$CF = \frac{\text{Actual kWh Produced}}{\text{Rated Power x 8760}}$$

Example

$$CF = \frac{\text{15,000 kWh}}{\text{5kW x 8760}} = 0.34$$

ESTIMATION OF ANNUAL ENERGY PRODUCTION

1. **GENERATOR SIZE**
2. **ROTOR AREA and WIND MAP**
3. **CALCULATED: HISTOGRAM & POWER CURVE**

GENERATOR SIZE

AEP = CF x GS x 8760

AEP	Annual energy production, kWh/yr
CF	Capacity factor (efficiency factor)
GS	Generator Size (rated power), kW
8760	# of hours in a year

GENERATOR SIZE EXAMPLE

AEP = CF x GS x 8760

CF	30% = 0.30
GS	5 kW = 5 kW
8760	# of hours in a year

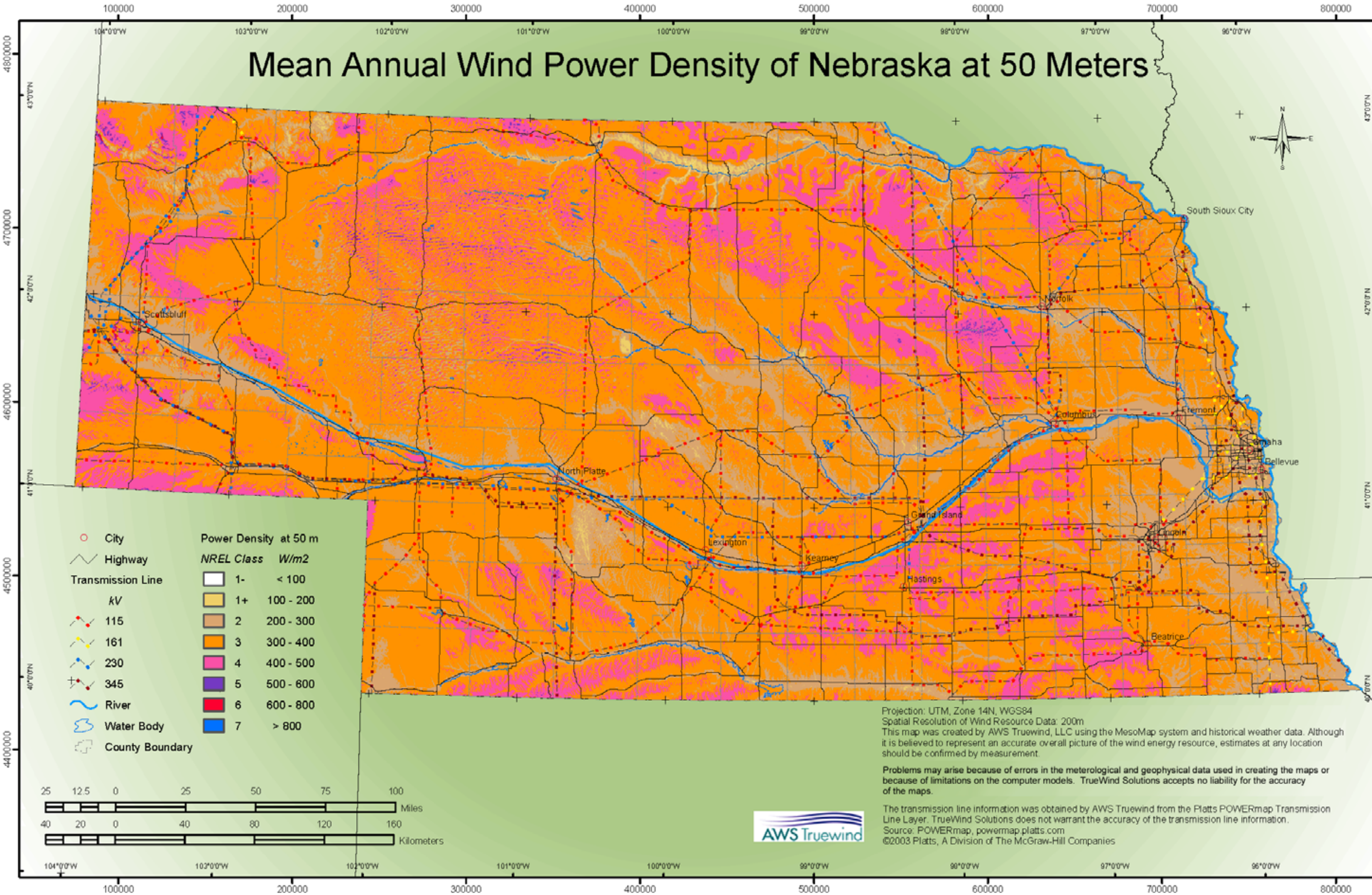
AEP = 0.3 * 5 * 8760

AEP = **13,140 kWh**

ROTOR AREA & WIND MAP

$AEP = CF \times Area \times WM \times 8.76$

AEP	Annual energy production, kWh/yr
CF	Capacity factor (efficiency factor)
Area	Rotor Area, m^2
WM	Wind Map Power, W/m^2
8.76	Hours in a year/ 1000 (converts Watts to kW)


Mean Annual Wind Power Density of Nebraska at 50 Meters
South Sioux City
Norfolk
Scottsbluff
Columbus
Fremont
Omaha
Bellevue
North Platte
Grand Island
Lexington
Kearney
Hastings
Lincoln
Beatrice
City
Highway
Transmission Line
kV
115
161
230
345
River
Water Body
County Boundary
Power Density at 50 m
NREL Class W/m2
1- < 100
1+ 100 - 200
2 200 - 300
3 300 - 400
4 400 - 500
5 500 - 600
6 600 - 800
7 > 800
25 12.5 0 25 50 75 100
Miles
40 20 0 40 80 120 160
Kilometers
Projection: UTM, Zone 14N, WGS84
Spatial Resolution of Wind Resource Data: 200m
This map was created by AWS Truewind, LLC using the MesoMap system and historical weather data. Although it is believed to represent an accurate overall picture of the wind energy resource, estimates at any location should be confirmed by measurement.
Problems may arise because of errors in the meterological and geophysical data used in creating the maps or because of limitations on the computer models. TrueWind Solutions accepts no liability for the accuracy of the maps.
The transmission line information was obtained by AWS Truewind from the Platts POWERmap Transmission Line Layer. TrueWind Solutions does not warrant the accuracy of the transmission line information.
Source: POWERmap, powermap.platts.com
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AWS Truewind

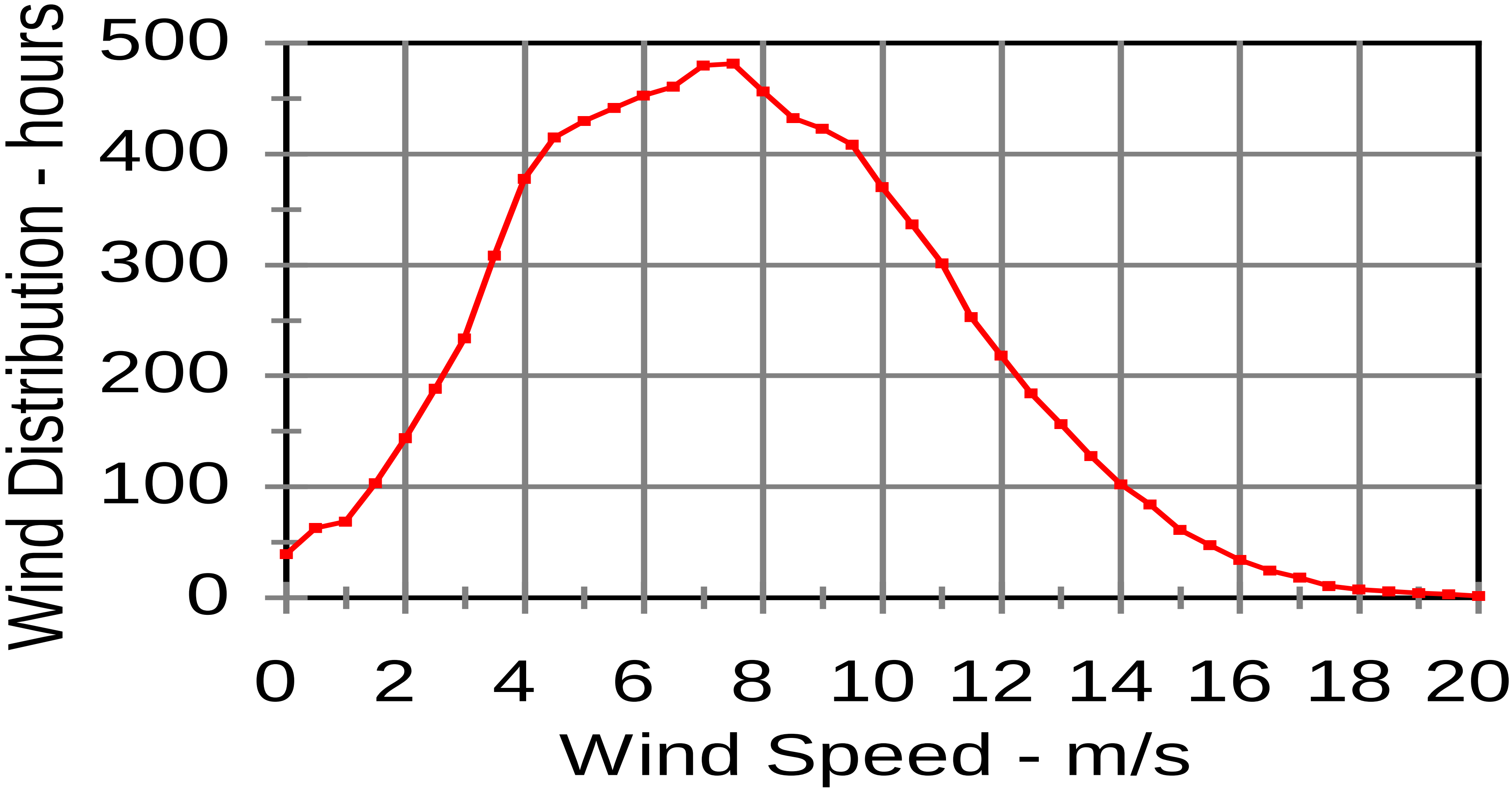
ROTOR AREA & WIND MAP EXAMPLE

AEP = CF x Area x WM x 8.76

CF	30% = 0.30
Area	25 m^2
WM	300 W/m^2
AEP =	0.3 * 23 * 300 * 8.76
AEP =	**19,710 kWh**

Annual Wind Distri

Amarillo, TX (1995-7,40 m



CALCULATED ENERGY PRODUCTION

WIND SPEED	POWER	BIN HOURS	ENERGY
m/s	kW	hr	kWh
1-3	0	1130	0
4	0	760	0
5	0.53	868	460
6	1.20	914	1,097
7	2.20	904	1,988
8	3.26	847	2,760
9	4.15	756	3,138
10	4.79	647	3,098
11	5.22	531	2,771
12	5.42	419	2,272
13	5.33	319	1,700
14	4.92	234	1,151
15	4.35	166	721
16	3.83	113	434
17	3.47	75	260
18	3.03	48	145
19	3	30	90
≥ 20	0	0	0
		8759	22,085

Rayleigh, 8.2 m/s at 40 m, STD

APPLICATIONS

- GRID CONNECTED
  - Generator with inverter
  - Induction generator
- BATTERY CHARGING
  - Direct DC
  - Inverter for AC
- WATER PUMPING
  - Mechanical
  - Electrical

APPLICATIONS (Cont)

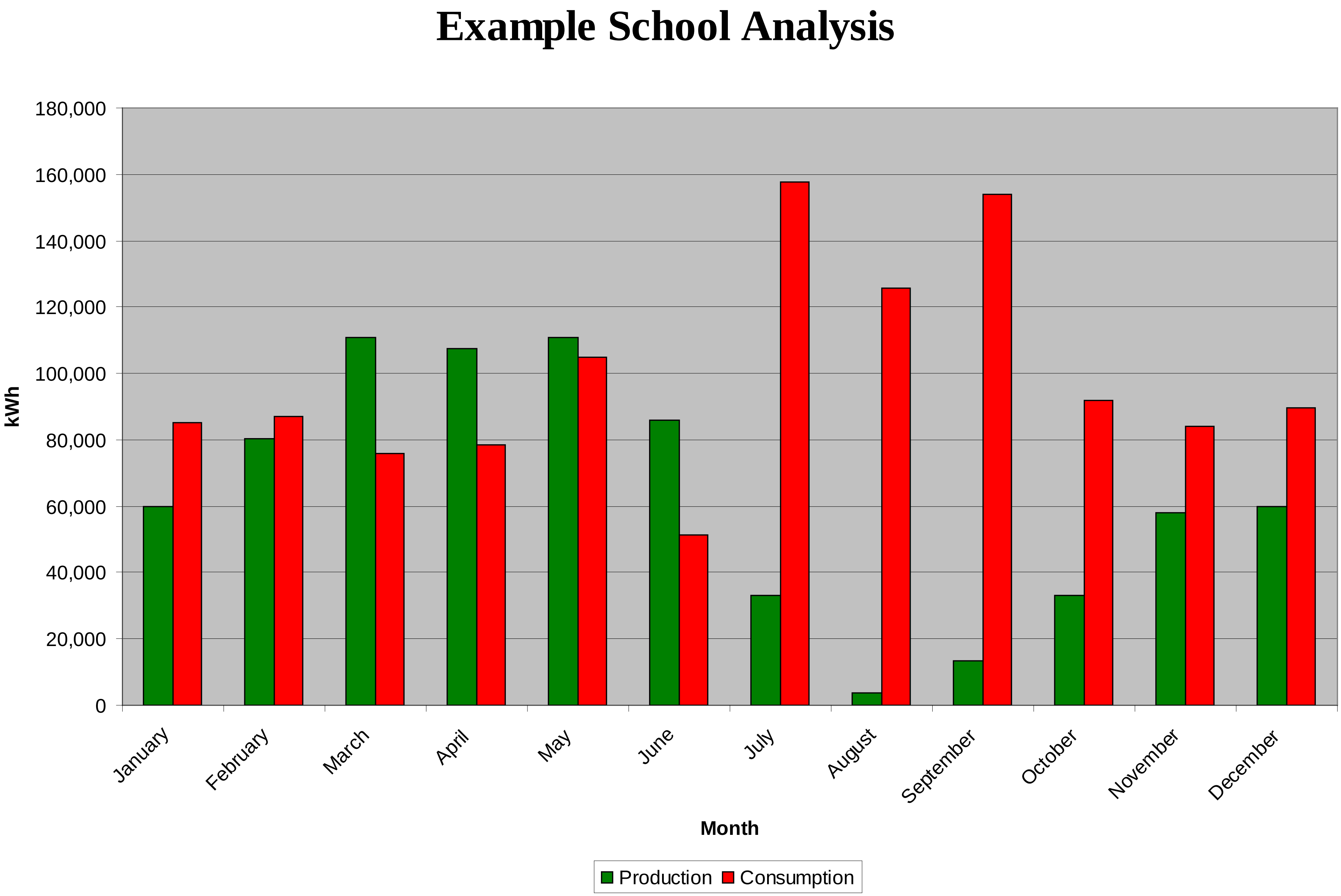
- TELECOMMUNICATIONS

  Hybrid generation: wind, solar, diesel

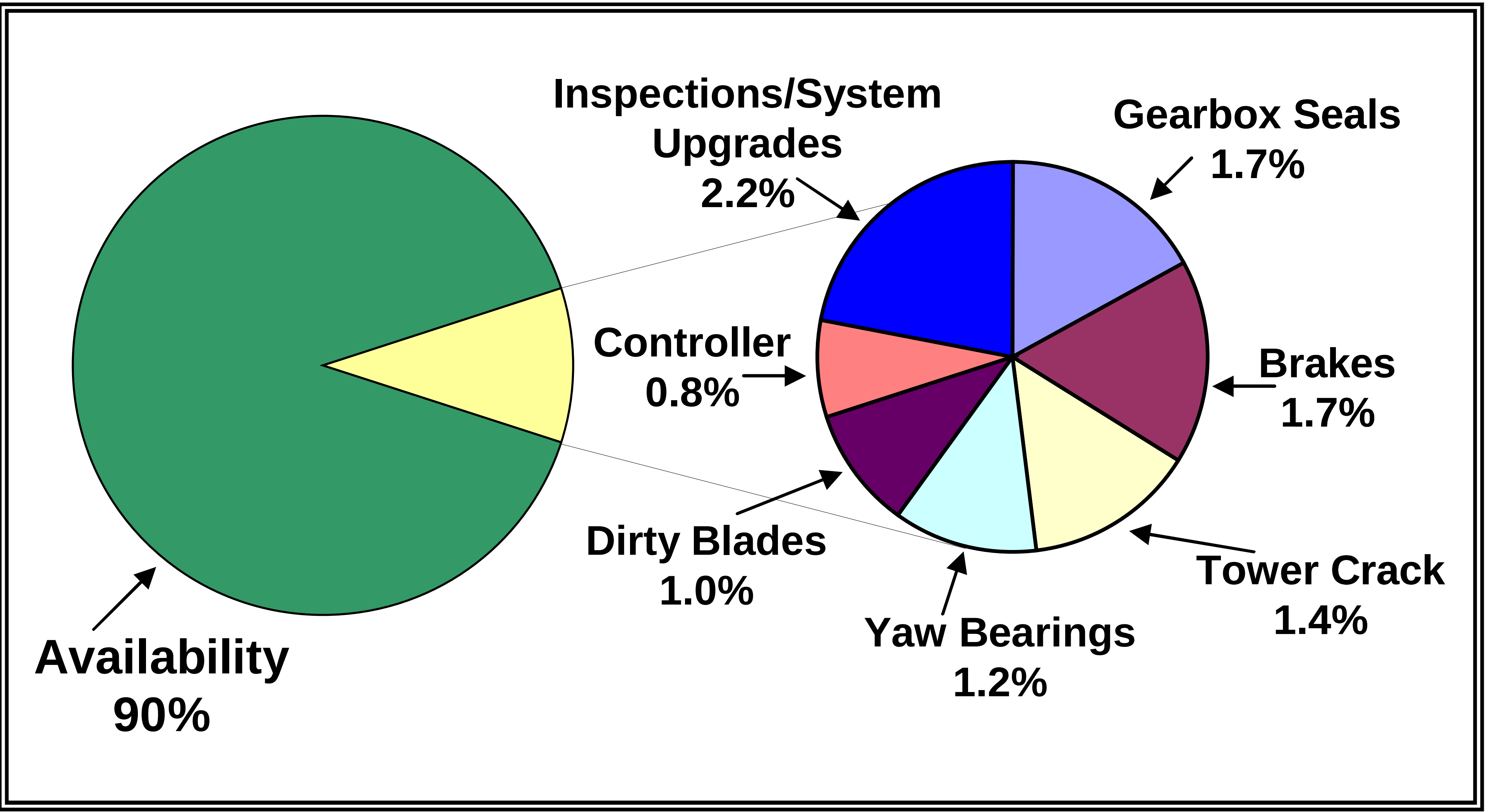
- VILLAGE POWER SYSTEMS

  Hybrid systems with existing diesels

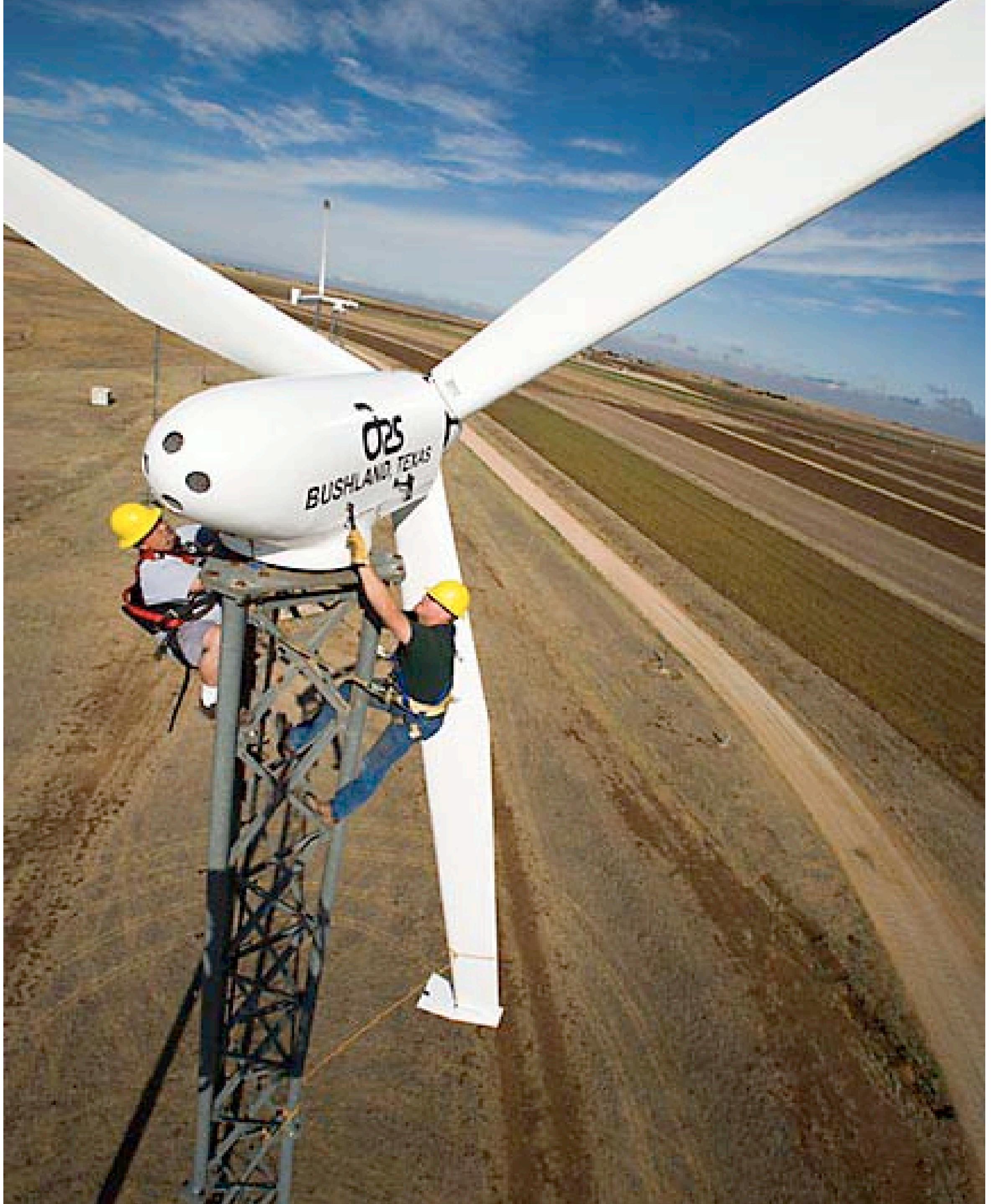
  New systems with wind, solar, diesel, storage


Example School Analysis
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
kWh
January
February
March
April
May
June
July
August
September
October
November
December
Month
Production
Consumption

Operating Experience over 20 yrs



Maintenance and Service

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Vertical Axis Turbines

The Need for Certification

- Performance specifications and tests are not standardized
- Consumers need greater assurance of safety, functionality, and durability
- Agencies providing financial assistance lack performance assurance
- Manufacturers indicate that certification is important to their business

Turbine Certification

- Uses *AWEA Small Wind Turbine Performance and Safety Standard*
- Includes Turbine Field Testing
- Conducted by an independent certification body *Small Wind Certification Council*
- *www.smallwindcertification.org*

Elements of the Certification

- **Rated Annual Energy**
  - Kilowatt-hours per year at a uniform wind speed
- **Rated Power**
  - Instantaneous power at a uniform wind speed
- **Rated Sound Level**
  - Level not exceeded 95% of time with a uniform average wind speed
- **Meets Safety and Durability Requirements**

Turbines Pending

Airdolphin GTO, American Zephyr Corporation
Bergey 5kW, BergeyWindpower Co.
Bergey Excel-S, BergeyWindpower Co.
Swift Wind Turbine, Cascade Engineering
Endurance S-343, Endurance Wind Power Inc.
Enertech E13, Enertech, Inc.
Evance R9000, Evance Wind Turbines Ltd.
Kestrel e400i 3kW 250V
Kestrel e400i 3kW 48V DC, Eveready Diversified Products (Pty) Ltd.
P15-50, Polaris America LLC

Turbines Pending (Cont)

10 kW Hummingbird, Potencia Industrial S.A.
Renewegy VP-20, Renewegy, LLC
AOC 15/50, Seaforth Energy
Skystream 3.7, Southwest Windpower
TTK-10kW, Taisei Techno Co
UrWind O2, UrWind Inc.
Ventera VT10, Ventera Energy Corporation
Windspire - 800040, Windspire Energy
ARE442, Xzeres Wind Corporation

Plan to join the research and development team!

Potential Lawn Art

Major Issues

Load Management

Storage

Economics