EVALUATING WIND ENERGY POTENTIAL IN LOUISIANA

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The purpose of this report is to present a methodology for assessing the onshore potential of utilizing the wind as a source of energy in Louisiana. Discussion of the many types of wind energy conversion devices, mechanical designs, system configurations, etc., is beyond the intended scope of this report. The reader is referred to the various references for information in these areas.

Wind energy conversion has a relatively low potential in Louisiana due to the relatively low wind velocities throughout the state. As a general rule, a minimum average annual wind velocity of 10-12 miles per hour (MPH) is required for an economical wind energy installation to be considered. The average annual wind speed is less than 10 MPH for 97% of the land area in Louisiana.[11] The remaining 3% of Louisiana has an average annual wind speed of less than 11.5 MPH, and this area is confined to a small area along the Mississippi River below Port Sulphur and along exposed shorelines of the Gulf of Mexico. Average annual wind speeds for various locations in Louisiana are provided in Table I.

Amount of Energy in Wind

Wind energy conversion devices or "wind machines" convert the energy of a moving stream of air into energy in a more useable form such as mechanical energy for operating water pumps or generating electricity. The energy available in a wind stream is a function of air density, the wind velocity, and the area intercepting the wind (the area swept by the wind machine blades). The power density of a wind stream at constant velocity V is given by

$$P/A = 0.05472V^3 \quad (1)$$

where P is power in watts, A is wind intercept area in square meters, and V is wind velocity in miles per hour. The combined term P/A is referred to as the wind power density. Using equation (1), the power density of wind at a constant velocity of 9 MPH is 39.9 watts per square meter (W/m^2). Since wind power is proportional to the cube of the wind speed, a wind stream of 18 MPH, which is only twice 9 MPH, has a power density of 319.1 W/m^2 which is eight times the power density of a 9 MPH wind. Small differences in wind speed make large differences in wind power.

The preceding power densities were calculated using constant wind speeds. The wind, of course, does not blow at a single constant velocity. To properly assess the wind power available at a given site, it is necessary to collect data on wind speed duration and frequency of occurence. The average annual wind speeds given in Table I give an overall idea of the amount of wind throughout the state, but use of these values in equation (1) will give erroneous results. For example, if the wind blows at 10 MPH half the time and at 20 MPH half the time, the average wind speed is 15 MPH. The power density at 10 MPH is 55 W/m^2 and at a 20 MPH it is 438 W/m^2 for a total available power of 247 W/m^2, which is 62 W/m^2 more than the 185 W/m^2 available in a steady 15 MPH wind. Also, wind machines have a "cut-in speed," which is the minimum wind speed necessary for the wind machine to operate. The cut-in speeds of most wind machines designed for electrical power generation are 8 to 12 MPH with a few at 7 MPH. A wind machine does not operate below the cut-in speed.

Wind power densities determined from measured wind speed duration and frequency of occurence offer a true picture of the available wind power. The average annual wind power densities in Table I were generated from data collected over a number of years. The wind power densities provided in Table I are representative of sites well exposed to the prevailing strong winds such as hilltops, ridge crests, large clearings, and other locations free of local obstructions to the wind. The values are not representative for sites with poor wind exposure such as narrow valleys, forested or urban areas, or sites downwind of hills and obstructions. The percentage of time a given wind power density is available is provided in Table II.

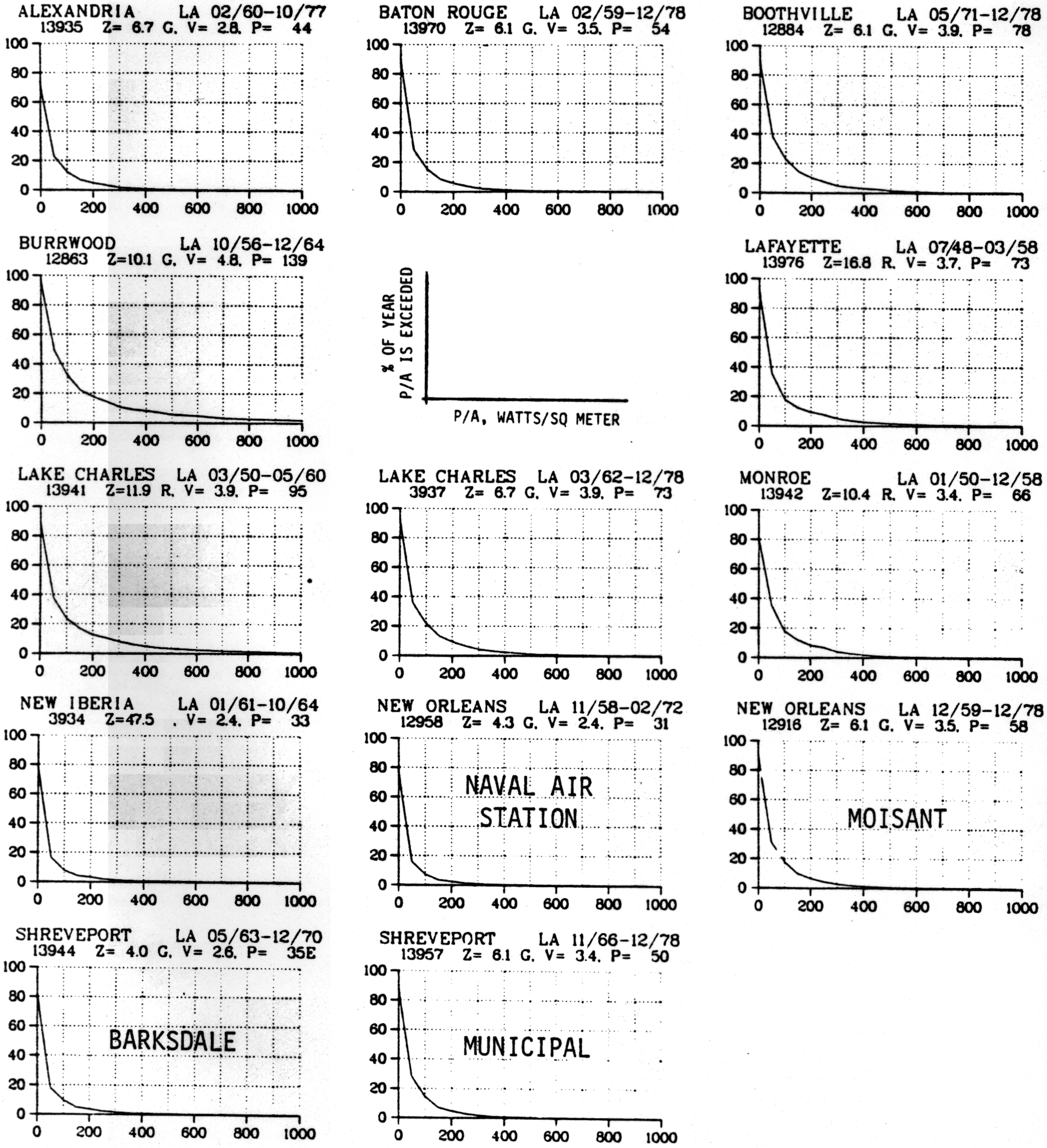
TABLE I[11]

AVERAGE ANNUAL WIND POWER DENSITY (W/m^2)
AND AVERAGE ANNUAL WIND SPEED (MPH)

STATION	LOCATION	YEARS OF RECORD	WIND SPEED AT 10m HEIGHT	POWER DENSITY AT HEIGHT OF	
				10m	50m
Alexandria	Esler Field Airport	17	6.7	52	104
Baton Rouge	Ryan Field Airport	20	8.3	67	133
Boothville	Weather Bureau Office	7	9.4	96	192
Burrwood	Special Purpose Office	8	10.7	139	276
Lafayette	Municipal Airport	10	7.6	59	117
Lake Charles	Airport	17	9.2	87	173
Monroe	Selman Field Airport	9	7.6	65	130
New Iberia	Airport	4	4.3	17	34
New Orleans	Moisant Int'l Airport	19	8.5	72	143
	Naval Air Station	13	6.0	45	89
Shreveport	Municipal Airport	12	8.3	62	123
	Barksdale AFB	7	6.5	52	104

TABLE II[11]

Percentage of Time a Given Wind Power Density P/A is Exceeded



Adjusting Wind Data for A Given Site

Wind data varies drastically from one location to another, depending on the surrounding terrain and obstructions. Average annual wind speed may measure 8 MPH in the open terrain of an airport; whereas, the average wind speed measured in a residential area one mile away may be only 6 MPH. A 6 MPH wind has only 42% of the available energy of a 8 MPH wind. This illustrates the need to measure the wind speed and frequency of duration at the actual site for at least a year in order to avoid error in applying wind data from another location.

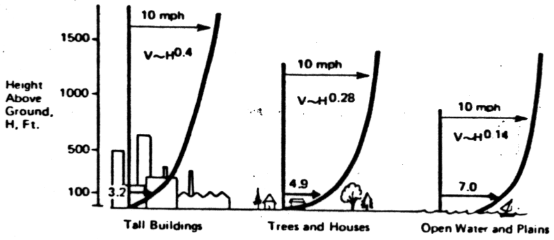
For preliminary evaluation purposes or when actual site data cannot be obtained, data from another site may be adjusted for height and terrain. When the average annual wind velocity V, or average annual power density P_1/A is known at a height above ground H_1, then V_2 or P_2/A may be estimated at another location and height H_2 with the following relationships:

$$V_2 = V_1 \left(\frac{H2}{H1} \right)^{a} \qquad (2)$$

$$(P_2/A) = (P_1/A) \left(\frac{H_2}{H_1} \right)^{3a} \qquad (3)$$

where the exponent a depends on surface roughness. Over smooth terrain or water a = 0.14. In moderate terrain with wind obstruction from trees and low buildings such as houses a = 0.28. Over rough terrain such as hills and tall buildings a = 0.40. These wind profiles are illustrated in Figure I.

FIGURE I

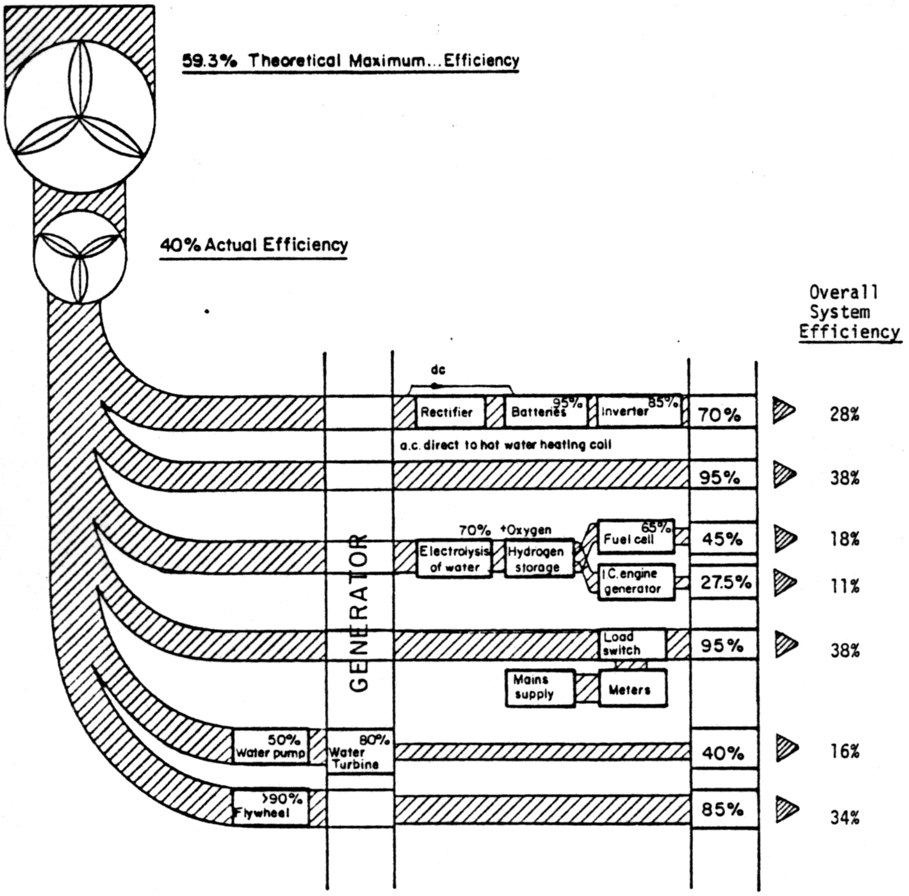


EFFECT OF GROUND ROUGHNESS
ON VERTICAL DISTRIBUTION
OF WIND SPEEDS

Amount of Power obtainable from a Wind Machine

The preceding information on wind power density applies to the amount of energy contained in the wind. All of the energy contained in a wind stream cannot be converted into useable power due to aerodynamic, mechanical, and electrical conversion inefficiencies. The maximum theoretical efficiency (the Betz coefficient) for converting wind energy to mechanical energy is 59.3%. Most wind machines have efficiencies lower than the theoretical maximum; 40% is typical of many modern wind turbine designs. Conversion of mechanical energy to electrical energy has a typical efficiency of 95%, for an overall efficiency of 38%. Power conditioning and energy storage schemes introduce further inefficiencies as shown in Figure II. Manufacturer's literature should be consulted for efficiencies and power curves for the specific wind machine under consideration.

FIGURE II[7]



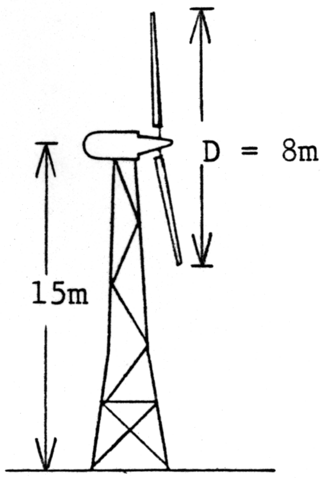
Overall conversion efficiency from wind energy to end use,

Example Calculation

The information presented in the previous sections is applied in the following example: A rural doctor's office wishes to evaluate installing a windmill to supply part of the electricity requirements. The installation will not have any energy storage capability (e.g., batteries). Anytime the windmill produces more power than is needed, particularly at nights and on weekends, the excess power will be metered into the utility grid and sold to the utility. Under consideration is a horizontal axis, three blade wind turbine with an alternator that will produce 10 KW at a rated wind speed of 22 MPH. The cut-in speed is 8 MPH and the rotor diameter is 8 meters (26 feet). The system described was chosen from a list of commercially available wind machines[2], and the manufacturer's power curves and data have not been ordered. The annual electricity consumption of the doctor's office is 43,200 kilowatt-hours (KW-HR). The rural office is located southwest of Shreveport.

Question: Is there enough wind to justify installation of the proposed wind machine?

The office is in a rural location approximately 30 miles southwest of the Shreveport Municipal Airport. Since wind data has not been collected at the office, wind data from the Shreveport Airport will be utilized. The wind machine will be located in an open field behind the office approximately 1000 feet from the nearest trees. The surrounding terrain is flat. The wind machine will be mounted on a 15 m (49 ft) tower.



Calculate the wind intercept area (A_T) of the horizontal axis wind turbine.

$$A_T = \frac{\pi D^2}{4} = \frac{(3.1416)(8m)^2}{4} = 50.3m^2$$

Calculate the average annual wind power density (P/A) at a height of 15m over smooth terrain by adjusting the wind data in Table I for the Shreveport Airport.

From Table I, the average annual wind power density is given as 62 W/m^2 at a height of 10m over smooth terrain. Using Equation (3),

$$(P/A)_{\substack{\text{annual}\\\text{average}}} = (P/A)_{\text{airport}} \left(\frac{H2}{H1}\right)^{3a}$$

From Figure I, a = 0.14.

$$(P/A)_{\substack{\text{annual}\\\text{average}}} = \left(62\ {}^{W}/{}_{m^2}\right)\left(\frac{15m}{10m}\right)^{3(0.14)}$$

$$= 73.5\ {}^{W}/{}_{m^2}$$

The wind turbine under consideration has a cut-in speed of 8 MPH. Since the wind turbine will not deliver any power at wind speeds lower than 8 MPH, the power contained in winds less than 8 MPH, (P/A) lost, must be subtracted from the above calculated power. Determine the wind power density of a 8 MPH wind from Equation 1.

$$(P/A)_{8\ \text{MPH}} = 0.05472\ V^3$$

$$= 0.05472\ (8)^3$$

$$= 28.0\ {}^{W}/{}_{m^2}$$

From Table II, winds at Shreveport Municipal Airport exceed power densities of 28 $^{W}/_{m^2}$ approximately 45 percent of the time; or, approximately 55 percent of the time, winds are less than 28 $^{W}/_{m^2}$ (8 MPH). To roughly estimate the amount of power to subtract for winds below 8 MPH, use the average of the power densities at 0 and 8 MPH.

$$(P/A)_{\text{lost}} = \frac{0 + 28.0}{2} = 14\ W/_{m^2}$$

The average annual wind power density above the cut-in speed, (P/A) useable, can now be estimated.

$$\left(\frac{P}{A}\right)_{\text{useable}} = \left[\left(\frac{P}{A}\right)_{\substack{\text{annual}\\\text{average}}} \text{x} \left(8760\ \frac{\text{hours}}{\text{year}}\right)\right] - \left[\left(\frac{P}{A}\right)_{\text{lost}} \text{x}\ (0.55)\left(8760\ \frac{\text{hours}}{\text{year}}\right)\right]$$

$$= \left[(73.5\ {}^{W}/{}_{m^2})(8760\ {}^{HR}/{}_{YR})\right] - \left[(14\ {}^{W}/{}_{m^2})(4818\ {}^{HR}/{}_{YR})\right]$$

$$= 643860 - 67452$$

$$= 576408\ \frac{\text{W-HR}}{m^2/\text{YR}} = 576\ \frac{\text{KW-HR}}{m^2/\text{YR}}$$

Calculate the available power in the wind intercepted by the 8 m turbine blades.

$$P_{\text{available}} = (P/A)_{\text{useable}} A_T$$

$$= \left|576 \frac{\text{KW-HR}}{\text{m}^2/\text{YR}}\right| (50.3\text{m}^2) = 28973$$

$$= 29{,}000 \frac{\text{KW-HR}}{\text{YR}}$$

Calculate the actual power the wind turbine can produce from the available power in the wind.

$$P_{\text{actual}} = P_{\text{available}} \times \begin{array}{l}\text{Overall system efficiency}\\ \text{from Figure II}\end{array}$$

$$= (29{,}000 \frac{\text{KW-HR}}{\text{YR}})(0.38)$$

$$= 11{,}020 \frac{\text{KW-HR}}{\text{YR}}$$

Therefore, the proposed windmill would be able to provide approximately 25% of the electricity requirements of the doctor's office at an initial investment of $21,000 or $1.90 per annual KW-HR capacity. Maintenance costs would have to be added to this. Also, efficiencies in Figure II are optimistic; many systems perform at efficiencies lower than those listed.

Although the selected wind turbine has a rated capacity of 10 KW at 22 MPH, there is only enough wind at the site for the turbine to generate an average of 1.26 KW per hour, maximum. Actually, the average power delivery would be even less because the turbine would be operating so far below its design capacity most of the time.

Answer: There is insufficient wind available to justify installation of a wind machine at the site chosen, based on current wind machine costs and efficiencies. The wind machine would require longer than its 25 year useful lifetime to pay for itself.

Utility Interconnection

Section 210 of the Federal Public Utility Regulatory Policies Act of 1978 (PURPA) requires utilities to purchase excess power from small scale producers at rates that are fair and non-discriminatory. The small scale producer must provide the necessary interconnect and safety equipment for feeding the power into the utility's grid, and the power produced must meet certain specifications to be fed into the grid. For more information on PURPA, contact the Louisiana Public Service Commission.

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Conclusion

Future improvements in wind machine performance, lower wind machine costs resulting from mass production, and higher conventional energy costs will all improve the economics for wind energy conversion. Although some coastal sites in Louisiana may offer opportunities for wind energy conversion, wind speeds are so low for inland sites that it is unlikely wind energy conversion will have any real potential in the state in the near future.

Conversion Factors

1 foot = 0.3048 meter

1 meter = 3.281 feet

1 mile per hour = 0.447 meter/second

1 meter per second = 2.237 miles per hour

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