THE OREGON STATE UNIVERSITY WIND STUDIES

Robert E. Wilson

Oregon State University
Corvallis, Oregon

This discussion concerns the work in progress done on engineering analysis of wind operated power for Oregon State University's Wind Power Project. The objective of the project is to assess the economic feasibility of commercial use of wind-generated power in selected areas of Oregon. Wind data collection and analysis is being accomplished by the Department of Atmospheric Sciences; the engineering work is centered in the university's Department of Mechanical and Metallurgical Engineering.

A number of machines for generating power have been examined. These include the Savonius rotor, translators, conventional wind turbines, the circulation controlled rotor and the vertical-axis winged turbine. Of these machines, the conventional wind turbine and the vertical-axis winged turbine show the greatest promise on the basis of the power developed per unit of rotor blade area.

The estimated cost of Palmer Putnam's 1500 kilowatt preproduction unit was updated from 1945 to 1971 using only the effects of inflation. Without taking into account the effects of 26 years advance in technology, the 1971 inflated cost was estimated to be $700 per installed kilowatt. The major cost component in Putnam's design was the rotor, which accounted for 43 percent of the total cost. As a result attention has been focused on the structural and fatigue analysis of rotors since the economics of rotary-winged, wind generated power depends upon low cost, long lifetime rotors.

Analysis of energy storage systems and tower design has also been undertaken. An economic means of energy storage has not been found to date. Tower design studies have produced cost estimates that are in general agreement with the cost of the updated Putnam 110-foot tower.

OREGON STATE UNIVERSITY WIND POWER PROJECT

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PROJECT STUDY AREAS

1. Wind data collection and analysis
2. Wind tunnel investigation of terrain modification
3. Engineering analysis of wind power systems.

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SCOPE OF ENGINEERING ANALYSIS

1. Energy storage schemes
2. Update of Putnam cost estimate
3. Wind generator performance analysis
4. Tower weight and loads
5. Identification of problem areas

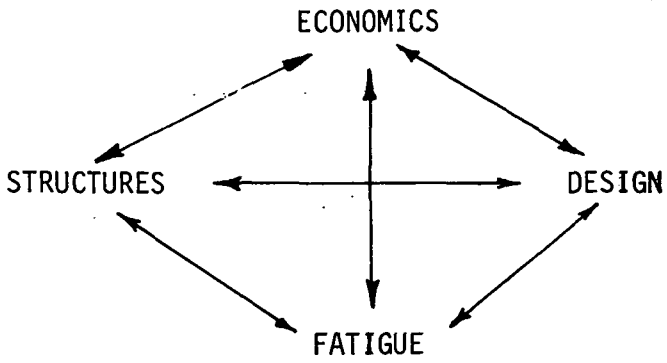
TYPICAL P.U.D. LOAD CHARACTERISTICS

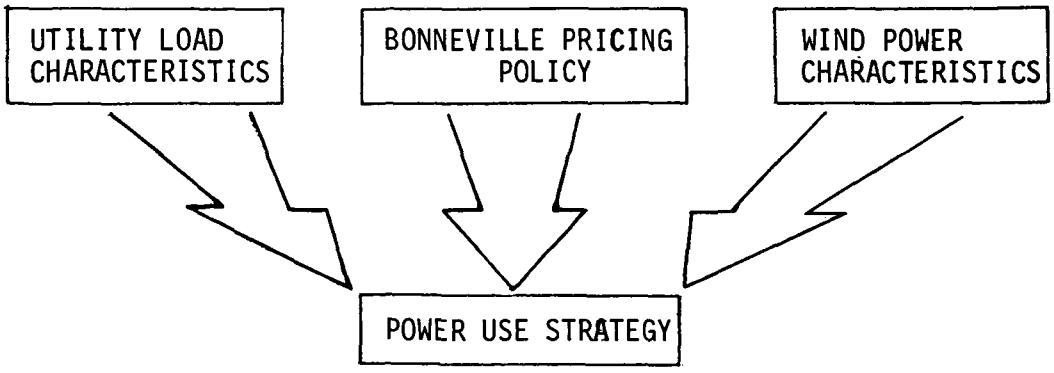
Load is split between residential and industrial

High incidence of electric heating

200 MW peak load

Peak load occurs in winter months





WIND POWER MACHINES

Standard

- Savonius
- Translators
- Propeller

Novel

- Vertical axis winged turbine
- Controlled circulation rotor

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MACHINE SURFACE AREA REQUIRED TO PRODUCE 1 MW IN A 30 MPH WIND

Machine	Area, ft^2	Tip Speed Ratio
Drag Translator	180,000	1/3
Lift Translator	600*	10
Savonius	60,000	1
Smith-Putnam	1,700	6
Vertical Axis Winged Turbine	1,700*	6

*$C_L = 1$, L/D = 15

COST SUMMARY OF PUTNAM DESIGN FOR 1945 AND FOR 1971

	1945 Cost Per Unit	Inflation Factor	1971 Cost Per Unit
ENGINEERING	$ 10,000		$ 20,000
MANUFACTURING			
1) Standard Equipment			
Generators	8,870	3.5	31,045
Main gears	20,344	3.72	75,680
Electric coupling	4,612	2.36	10,884
Governor	2,508	3.50	8,778
Bearings	16,282	3.5	56,987
Switch gear	5,125	2.55	13,069
Coupling, flexible	1,970	3.5	6,895
Elevator	2,665	3.5	9,327
Service hoist	1,680	3.5	5,880
Miscellaneous electrical	2,100	2.3	4,955
Tower (includes erection)	21,395	3.6	77,022
Paint	691	3.5	2,418
Subtotal	$ 88,242		$ 302,940
2) Rotor Components			
Blades	29,480	3.72	109,666
Hub assembly	42,935	3.72	159,718
Pintle assembly	48,600	3.72	180,792
Patterns, tools, jigs	800	3.72	2,976
Subtotal	$121,815		$ 453,152
INSTALLATION			
Freight	2,054	3.0	6,162
Land	0	0	0
Roads	7,460	3.43	25,587
Erection	30,000	3.43	102,900
Total Installed Cost	$260,071		$ 910,741
CONNECTION			
Transformers	3,600	1.92	6,912
High line	15,000	2.55	338,250
Unit cost	$278,671		$ 955,903
Contingency 10%	27,867		
	$306,538		$1,051,493

TOWER ANALYSIS

Design based on

1. Pinned joint truss
2. $\sigma_{allowable}$ = 17,000 psf
3. 60 mph wind loads
4. Dead weight at top = 500,000 lbs
5. Wind loads from "Smeaton table"
6. Design factor of 2

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TOWER WEIGHT

Tower Height	Weight
70 ft	13,000 lbs
120 ft	38,000 lbs

Sensitivity at h = 120 feet

$$\frac{\partial \text{ Weight}}{\partial \text{ Height}} = 1000 \text{ lbs/ft}$$

$$\frac{\partial \text{ Weight}}{\partial \text{ Topload}} = 0.03$$

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FURTHER STUDY

Prediction of rotor life

Energy storage system technology

Wind power regulating agencies

Aerodynamic analysis

Vibration analysis