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Survey of Historical and Current Site Selection Techniques for the Placement of Small Wind Energy Conversion Systems

December 1977

**Prepared for
Pacific Northwest Laboratory
under Agreement No. B-3602-A-E**

Pacific Northwest Laboratory
Richland, Washington 99352
Operated for the
U.S. Department of Energy
by



MASTER

BNWL-2220-WIND-9

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UC-60

SURVEY OF HISTORICAL AND CURRENT SITE
SELECTION TECHNIQUES FOR THE PLACEMENT
OF SMALL WIND ENERGY CONVERSION SYSTEMS

American Wind Energy Association
c/o Windworks
P. O. Box 329, Route 3
Mukwonago, WI 53149

PREPARED FOR
PACIFIC NORTHWEST LABORATORY
UNDER AGREEMENT NO. B-3602-A-E

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PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON 99352
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FOREWORD

This report was prepared for Battelle, Pacific Northwest Laboratory (PNL) as part of Special Agreement B-36302-A-E between PNL and the American Wind Energy Association (AWEA). The objective of the work was to provide PNL with background information on historical practices in siting small wind energy conversion systems. The information in the report describes the approach taken by AWEA and presents conclusions and recommendations based upon their experience.

PNL intends to combine the conclusions and recommendations presented by AWEA with results of its own analysis of the data for use as input in planning for the Wind Characteristics Program Element of the Federal Wind Energy Program.

The efforts and cooperation of the offices and members of AWEA who contributed to this work are greatly appreciated.

J. V. Ramsdell
Contract Technical Monitor
Battelle, Pacific Northwest Laboratory

CONTENTS

FOREWORD	iii
1. INTRODUCTION	1
2. CONCLUSIONS AND RECOMMENDATIONS	1
3. APPROACH	2
4. DISCUSSION	5
4.1 Siting WECS for Pumping Water	6
4.2 Siting WECS for Generating Electricity	7
4.3 Current WECS Siting Guidelines	7
4.4 Future Siting Guidelines	9
5. PRINCIPAL FINDINGS	10
6. REFERENCES	11
APPENDIX A - LIST OF NEWSPAPERS CARRYING SITING STUDY ADS	13
APPENDIX B - SAMPLE QUESTIONNAIRE AND RESPONSES	19
APPENDIX C - PAST AND PRESENT WECS DISTRIBUTORS	28
APPENDIX D - SITING GUIDELINES	31
APPENDIX E - WIND ENERGY BIBLIOGRAPHY	44
ACKNOWLEDGMENT	71

1. INTRODUCTION

Individuals and groups who purchase and install wind energy conversion systems (WECS) for either generation of electricity or pumping water have to go through a process by which a specific location is selected for each WECS. The purpose of this study was to identify and document methods and practices used in siting of WECS. The study covers the period from the early 1900s to the present day.

The process of WECS siting is not exclusively a meteorological concern, but represents a balance between the economic and technical considerations and social values of the user. Site selection can be a critical factor in determining the economic viability of a given wind system installation. This is demonstrated by the Smith-Putnam experimental wind turbine built in Vermont in 1941. The mean wind speed at the site was over-estimated to such an extent that the energy obtained was only 1/3 the expected value.⁽¹⁾ The economics of today's numerous energy sources are highly competitive unlike the historical applications of wind energy.

Tools employed in the siting process to carefully assess a given wind installation are evolving as a more complex technology than previously employed. This is in part due to an increased understanding of the variables involved in siting and recognition of the need to quantify the intuitive understanding gained in thousands of past WECS installations.

The systematic development of siting technology in part, requires an understanding of historical siting practices.

2. CONCLUSIONS AND RECOMMENDATIONS

AWEA concludes that:

- WECS in general were used where there was an intuitively understood "minimal availability" of wind energy.
- Water pumping systems were sited on the basis of availability of water.
- Electric generating systems were sited on the basis of rough "rules of thumb," generally a minimum height above obstacles within a specified radius.

- Current distributors of WECS are using these historical "rules of thumb" in addition to inexpensive anemometry and simplified data reduction techniques.
- Current distributors are inclined to take advantage of advances in siting hardware and techniques.

AWEA recommends that:

- A program be developed that more fully disperses recent developments in WECS siting to the end user. Elements of this program could include:
 - WECS dealer siting seminars
 - Extension agent siting seminars
 - Siting handbooks
 - Presentation of existing wind data in a form appropriate for use by non-technical user groups.
- A program be developed that assesses all present siting techniques in terms of WECS applications. These applications vary in relation to:
 - WECS size
 - End power use
 - Accuracy required
 - Topography

3. APPROACH

Since siting procedures ultimately relate to the sale of a wind machine, answers to questions such as:

- How were wind machines sold?
- How were wind machines sited?
- How were wind machines installed?
- What was the correlation between sales statements made from siting studies and the actual experience after installation? (How accurate were performance predictions?)

offer insight into the technology used. This study has been conducted to collect and compile information which will provide answers to these and other siting related questions.

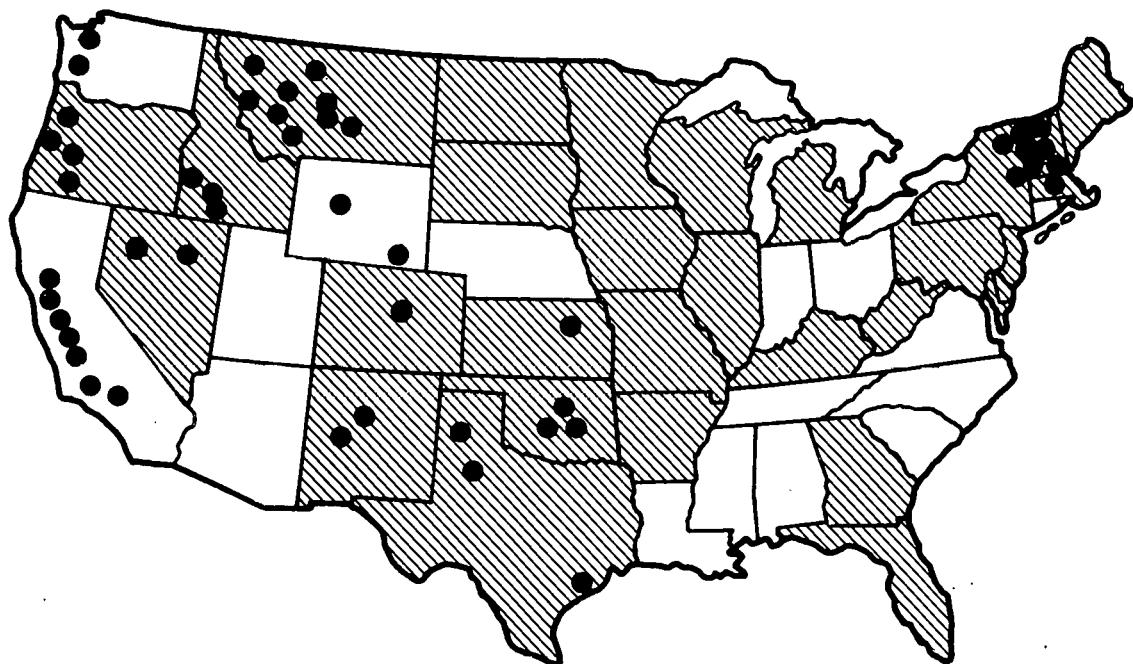
The American Wind Energy Association (AWEA) conducted the study through questionnaires, interviews and a literature search. Ads seeking sources of information on WECS siting were placed in local newspapers in geographic regions where WECS were widely used. (See Appendix A for a list of papers in which ads were placed.) Respondents were mailed an interview questionnaire. A total of 600 questionnaires were mailed out and 175 were returned. The return rate for this portion was 29%. A total of 158 returned questionnaires were validated using data on ownership of WECS. Those questionnaires not validated were returned by interested parties who had not owned a WECS. The questionnaire used is presented in Appendix B. Responses to the questions are tabulated in the Appendix by both number and as a percentage of total responses.

Personal interviews were conducted in the west, midwest, and mountain regions of known past high populations of WECS to gain additional information. Institutional buyers of old WECS were contacted to identify areas in which they found machines, and where possible to identify specific past owners. Where wind machine towers were seen while driving, a stop was made and an interview was attempted. Generally, it was found that present owners of WECS installations are two, sometimes three owners removed from the original owner. Interviews were found to be time consuming, but often very valuable. This was particularly true when past dealers of WECS and ranchers with large numbers of WECS were willing to discuss their experiences.

Many prime resources for interviews and discussions of past techniques have recently passed away, and literature on the specific subject of historical WECS siting techniques was not extensive. Thus, the personal interviews have been important. It is surmised that this study, if conducted a few years hence, would have yielded little direct data.

Interviews were also conducted with academic and institutional researchers currently involved with atmospheric sciences and siting technology. It is clear that correlations exist between past and present thinking.

Siting information was sought from past and present distributors of WECS. Appendix C presents a list of the distributors contacted. In addition, Figure 1 shows the regions of the U.S. which were covered by the survey and by the AWEA team in its travels.



- STATES FROM WHICH RESPONSES TO QUESTIONNAIRES WERE RECEIVED
- POINTS VISITED

FIGURE 1. Regions of the U.S. Covered by the Siting Survey and the AWEA Travels

The literature review, while not finding a great deal of information explicitly on WECS siting, did identify siting guidelines offered by WECS manufacturers. Excerpts from these guidelines are contained in Appendix D. A listing of the literature related to wind energy, wind energy conversion and wind energy conversion systems which was reviewed is presented in Appendix E. In the Appendix, the listings of significant papers and reports have been annotated.

4. DISCUSSION

Extensive analysis of the results of the questionnaire has not been attempted, nor was it a part of the current study. The discussion which follows is based primarily upon responses to individual questions in the questionnaire as tabulated in Appendix B, and information gained during interviews and from the literature related to WECS siting.

The number of WECS represented in this study is 2,326. This includes responses from two ranches with over 1,000 water pumpers each. Not considering these two large groups of water pumpers, the percentage of WECS used for water pumping is 95%, the remaining 5% are for generating electricity. We feel this approximates the distribution of machines currently in use.

Table 1 illustrates the breakdown of data collected relative, essentially, to application and time of installation. It is felt that for relative application comparison, it is reasonable to synthesize the figure without the large water pumper users as these machines were less affected by the Rural Electrification Administration (REA). REA installed lines to the houses which used WECS, but not to the fields which used water pumpers. Some 500,000 wind electric systems are known to have been built, but most fell into disuse because of the REA.

WECS covered in the study were installed prior to 1961 and after 1970, as shown in Table 1. Prior to this break, the majority of the WECS installed were for water pumping, while since the break the majority have been electrical generating systems. The decreasing number of installations from the 1936-1940 period to the 1946-1950 period, and the few installations from 1951-1970 indicate the decreasing interest in utilization in wind energy conversion. The

TABLE 1. Dates of Installations

<u>Period</u>	<u>Mechanical</u>	<u>Electrical</u>
prior to 1910	97	0
1910 - 1915	3	1
1916 - 1920	4	1
1921 - 1925	3	1
1926 - 1930	7	1
1931 - 1935	2	4
1936 - 1940	87	4
1941 - 1945	26	7
1946 - 1950	2	4
1951 - 1955	0	1
1956 - 1960	0	2
1961 - 1965	0	0
1966 - 1970	0	0
1971 - 1975	1	27
1976 - present	<u>0</u>	<u>12</u>
	<u>232</u>	<u>65</u>

(This chart does not include users who had over 1,000 machines each.)

Total number of machines represented in the study: 2,236

water pumpers: 95% electrical: 5%

Total number of questionnaires mailed: 600

	<u>Total</u>	<u>Validated</u>
Total number of questionnaires returned:	175	158
Return rate:	29%	26%

WECS installations since 1970 indicate the resurgence in interest. The shift in type of WECS installed from mechanical water pumping to electrical generation reflects a renewed interest in electrical generation, although the actual ratio of new WECS installations may not be as one-sided as the Table indicates.

4.1 Siting WECS for Pumping Water

The siting of water pumping WECS was straightforward, governed primarily by the availability of water. The typical tower height for these machines was 30 ft, with higher towers used primarily when the machine was located in

a draw. Water pumping machines are still widely used for supplying range water. The marketing system, within specific geographic areas, is well established. There are a number of small companies (3 to 5 employees) in the Southwest and Plains states that install and maintain these machines on a full-time basis.

There is no indication from the questionnaires received or the interviews conducted that the present distributors or users of wind machines for pumping water would be willing to invest a significant amount of time or money in siting surveys. This is perhaps a result of the experience gained with the machines currently in use. It also reflects the fact that most machines are installed in regions of demonstrated wind energy potential.

4.2 Siting WECS for Generating Electricity

The siting of WECS for generating electricity incorporated much of the experience of long time dealers of water pumping machines. Still guided by intuitive feelings and "rules of thumb," rather than data collection and reduction, siting guidelines were described in owner's manuals.

Generally in the sale of electrical generation systems, no representations were made about specific performance. While manufacturers claimed performance (e.g., 500 kWh/mo for Model X), dealers sold the machines on experience gained locally. Dealers sold a WECS to charge a given number of batteries, or to power a certain number of lights. No claims were made regarding actual energy production.

Response to question 3 of the siting questionnaire indicates that in the past WECS for electrical generation were expected to provide power primarily for radios and home appliances using batteries as the storage medium. Most of these systems were installed by the owner on a tower with a height of 30 to 50 ft (see Questions 6 and 7, Appendix B). From question 18 it was found that a majority of the respondents (73%) were satisfied with the operation of their system, in that it provided as much power as was expected previous to installation.

4.3 Current WECS Siting Guidelines

As stated before, manufacturers of WECS generally offer some form of siting guidelines. Table 2 summarizes the siting recommendations of eight

TABLE 2. Summary of Siting Recommendations

Source	Minimum Height Above Obstacles	Within a Radius of	Comments
1. Jacobs ²	20 ft	100-200 ft	"Don't sacrifice a better location to save a few feet of wire."
2. WinPower ³	20 ft	500 ft	Refused financing to customers who did not follow their siting recommendations.
3. Allied ⁴	25 ft	500-1000 ft	"The standard distance for the tower is 90-100 ft from the batteries, but if higher ground and better wind currents can be secured...the tower should be set at the better location."
4. Dunlite ⁵	15-20 ft	50-300 yds	The range is given for the difference between upwind and downwind obstructions. A minimum tower height of 40 ft is recommended.
5. Winco ⁶	15 ft	400 ft	(see Figure D-2 in Appendix D)
6. North Wind ⁷	20 ft	500 ft	(see Figure D-3 in Appendix D)
7. Enertech manual ⁸	20-30 ft	400 ft	Like Aerowatt, Enertech suggests using ribbons to detect turbulence.
8. Aerowatt ⁹	not specified		Aerowatt guarantees their units only if after receiving a survey of the site, it agrees with the location.

past and present WECS manufacturers and distributors. The complete set of guidelines from which the summary was drawn is contained in Appendix D. The siting guidelines generally recommend that WECS be installed 20 ft or more above obstacles within a radius of 300 to 500 ft.

4.4 Future Siting Guidelines

As the capital investment required for WECS increases, selecting the proper installation site and evaluating the probable output become increasingly important. Approximately 60% of those individuals answering question 9 of the questionnaire indicated that they knew the wind speed in their area. However, the knowledge of annual average wind speeds in a given area was either non-existent (approximately 75% of the questionnaires returned) or grossly over-estimated. For example, a number of people estimated their annual average wind speed to be 25 mph, while according to National Weather Service Data, the annual average was actually 11 to 12 mph for their area.

The responses to questions 20 and 24 provide a guide to the thoughts of potential WECS users about the siting expenses they are willing to accept. These responses are shown in Table 3. It should be noted that expenses to determine available wind power are more acceptable than those to determine the best location for WECS installation. Specifically, 31% of the respondents to question 20 would be willing to spend more than \$250 to determine wind power availability, while only 3% of those responding to question 24 would be willing to spend that much for determining the best location. However, Table 3 shows that 57% of the respondents to question 24 would spend more than \$10 to determine the best locations. This indicates that simple guidelines on selecting the best location would be used.

The responses to questions 22 and 23 indicate that the farm machinery or WECS dealer is the individual most likely to be consulted in selection of a specific location for WECS, while the National Weather Service is most likely to be consulted for information of wind in the area.

By way of contrast, it should be noted that some respondents to the questionnaire answered only the questions they thought applied to their case. In some of these cases, they felt no need for future siting work, perhaps due

TABLE 3. Responses to Questions Relating to Acceptable Siting Expenses to Determine Wind Power Availability at a Farm and to Identify the Best Location for a WECS Installation on a Farm

<u>Siting Expense</u>	<u>Power at Farm</u>	<u>Best Site on Farm</u>
<\$10	27%	43%
11-50	22	37
51-100	10	9
100-250	3	8
250-500	31	2
>500	6	1

to success they had had with a WECS installation. From a topographic standpoint, the respondents' conclusions may be reasonable, especially when one considers many of these installations were in flat regions of known high annual average winds.

5. PRINCIPAL FINDINGS

The primary findings of this study follow:

- The primary factor in selecting the location for a WECS on a given site was the application of the power. Water pumping machines are constrained by the availability of water, and electric generating machines constrained by the location of the batteries. This was amplified by the fact that most wind electric systems prior to 1945 were low voltage (32 vdc), high amperage machines requiring heavy gauge wire.
- When meteorological factors affected the selection of machine location or tower height, such factors were dealt with on a basis of intuitive understanding gained from years of experience, as well as general guidelines supplied by WECS manufacturers.
- With the location of the machine determined by the application of the power, the next factor in the siting process was the selection of tower height. System distributors indicate that tower height decisions were

often made on the basis of tower cost, while machine owners indicate that tower height was selected to clear obstructions.

- In the application of wind energy to pumping water, some issues that affected site selection and tower height were non-meteorological. Among these were the fact that the tower was used to facilitate the drilling and casing process, and in the presence of abundant water, the WECS were moved to sites the rancher or farmer wanted grazed.
- The widely applied rule of thumb for selecting tower height was that the tower be 15 to 25 ft above obstructions within a 300 to 500 ft radius. The owner's manuals of the period state that dissatisfaction with performance is primarily the result of improper siting.
- While approximately 95% of those responding used wind machines for water pumping, nearly 75% of those responding indicated they would like to use wind energy for electrical applications in the future.
- The most often cited source of information on site selection was the WECS salesman or dealer (53%).
- Questionnaire responses most often cited the National Weather Service (NWS) (35%) as the source of information on wind data they would use. It is unclear if those responding to the questionnaire know how to get data from NWS, what type of data to request, or what to do with it once obtained.
- Current dealers are using low cost wind-run, and recording anemometers to assist in site selection.

6. REFERENCES

1. P.C. Putnam, Power From the Wind, Van Nostrand, NY, 1948.
2. Jacobs Owner's Manual. Available from North Wind Power Co., Warren, VT.
3. WinPower Owner's Manual. Available from the American Wind Energy Association (AWEA), Bristol, IN.
4. Allied Owner's Manual. Available from the AWEA.

5. Dunlite Owner's Manual. Available from EnerTech, Inc., Norwich, VT.
6. Winco Owner's Manual. Available from Winco, Minneapolis, MN.
7. North Wind Catalogue. Available from North Wind Power Co.
8. EnerTech Manual. Available from EnerTech, Inc.
9. Aerowatt Owner's Manual. Available from Pennwalt Corp., Houston, TX.

APPENDIX A

LIST OF NEWSPAPERS CARRYING SITING STUDY ADS

Advertisements were placed in local newspapers in geographic regions where WECS were widely used. The purpose was to seek sources of information on siting techniques used. The following newspapers carried the siting study advertisements.

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LIST OF NEWSPAPERS CARRYING SITING STUDY ADS

Eastern and Central Time Zones

Alabama

Times	News
Demopolis	Red Bay

Arkansas

Southern Standard	Independent	Express
Arkadelphia	Carlisle	Charleston
Greenwood Democrat	Wynne Progress	
Greenwood	Wynne	

Florida

Herald	Florida Filed Report
Havana	Orlando

Georgia

Farmer & Consumers	The Poultry Times
Market Bulletin	Gainsville
Atlanta	

Illinois

Northwestern IL Farmer	News	Atkinson-Annan
Lena	Altamont	News
Illinoian Star		Atkinson
Beardstown		

Iowa

Iowa Farm Bureau	Advertiser	Tri-County
Spokesman	Ames	Special
Grundy Center		Auburn

Shelby County Shopper Guide
Harlan

Kansas

High Plains Journal	Drovers Journal	Capper's Weekly
Kansas	Kansas City	Topeka

Kentucky

Messenger	Commonwealth	Greenup News
Madisonville	Journal	Greenup
	Somerset	

Louisiana

Star Plus
Hammond

Point Coupee Banner
New Roads

Maine

Coastal Journal
Bath

Franklin Journal & Farmington
Chronicle, Farmington

Maryland

Queene Anne's Record-
Observer, Centerville

News and Farmer
Preston

Massachusetts

Christian Science Moniter
Boston

The Cape Codder
Orleans

South Shore News
Rockland

Michigan

Holland Flashes
Allegan

Shopper Guide
Caro

Courier
Charlevoix

Review
Richmond

Farmers Advance
Camden

Minnesota

Norman County Index
Ada

Sentinel
Bricelyn

Scotsman
Cambridge

Livewire
Jackson

Sentinel
Sanborn

Tribune
Truman

Mississippi

Moniter-Herald
Calhoun City

Delta Farm Press
Clarksdale

Itawamba County
Times, Fulton

Missouri

Belton-Granview Shopper
Belton

Buchanan Co. Farmer and Grower
Gaxette, Faucett

St. Clair County Courier
Osceola

Times
Altamont

Free Press
Troy

Journal of Livestock & Agricultural
Saint Joseph

Nebraska

Journal
Crofton

Livestock Market
Digest
Norfolk

Business
Farmer
Scottsbluff

<u>New Hampshire</u>		
Shopper News Keene	Citizen Publishing Laconia	
<u>New Jersey</u>		
R&L Suburban News Franklin News	Advertiser Franklinville	Colonial News Freehold
<u>New York</u>		
Jefferson County Journal Adams	Albion-Holly Pennysaver Albion	Advertiser Alden
Dairy News Pearl River	Ballston Journal Ballston	MoneySaver Shoppers Guide Bolivar
<u>North Carolina</u>		
Village Advocate Chapel Hill	Southeastern Times Clarkton	Courier Clemmons
Herald & Ruralite Sylva		
<u>North Dakota</u>		
Advertiser Dickenson	Dicky County Leader Ellendale	Teller Milnor
The Forum Fargo	News Minot	
<u>Ohio</u>		
Farmland News Archbold	Firelands Farmer New London	Farm and Dairy Salem
<u>Oklahoma</u>		
Advocate Allen	Logan County News Crescent	Grand Lakes Shoppers Guide Grove
Lake Keystone News Mannford		
<u>Pennsylvania</u>		
Advertiser McMurray	Shopping News of Lancaster County Ephrata	
Bucks-Mont Courier Harleysville	News Lancaster	Lancaster Farming Lititz
<u>Rhode Island</u>		
Narragansett Wakefield		

South Carolina

Sentinel
Pickens

Williston Bay
Barnwell

News
Westminster

Southeastern
Farm Press
Columbia

South Dakota

Courier
Bison

Trader
Pierre

Record
Arion

Tribune Register
Tyndall

Reminder
Mobridge

Leader
White

Tennessee

Jackson County Sentinel
Gainsboro

Cannon Courier
Woodbury

Southeastern
Farm Weekly
Knoxville

Texas

News
Bogata

Southwest Farm Press
Dallas

Tribune
Calvert

Weekly Livestock
Reporter
Fort Worth

Hopodar
West

Texas Ranch
News
San Antonio

Virginia

Courier-Record
Blackstone

Farm & Livestock
Boyce

The Chronicles
of the Horse
Middleberg

West Virginia

Calhoun Chronicle
Grantsville

The Valley Digest
Lewisberg

Advocate
Parsons

Wisconsin

Wild River Advertiser
Frederic

Wisconsin State Farmer
Waupaca

Enterprise-Herald
Luck

Times
Peshtigo

Badger Farm Bureau
News, Madison

Home News
Spring Green

Manitoba

Free Press Report on Farming

Ontario

Western Ontario Farmer

Saskatchewan

Western Producer

New Brunswick
Gleaner

Rocky Mountain Time Zone

Arizona

Apache Sentinel Apache Junction	Buckeye Valley News, Buckeye	Eastern Arizona Courier, Safford
Tombstone Epitaph Tombstone	News-Enterprise Yuma	

Colorado

Adams County Standard Brighton	Record Stockman Denver	Enterprise Holyoke
Arkansas Valley Journal La Junta	Pioneer Yuma	

Idaho

Eastern Idaho Farmer Idaho Falls	The Owyhee Nugget Marsing	Citizen Preston
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Montana

Montevideo News Billings	Pioneer Ronan	Herald Sidney
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Madisonian
Virginia City

New Mexico

Sandoval County Progress Bernalillo	Mid Valley Observer Corrales	Round-up University Park
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Utah

Millard County Progress Fillmore	Clearfield Courier Roy	Express Vernal
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Wyoming

Palatte County Record Times, Wheatland	Post Pine Bluffs	Guide Review Lingle
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North Wyoming News
Worland

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APPENDIX B

SAMPLE QUESTIONNAIRE AND RESPONSES

The following pages present a sample of the questionnaire that was sent to respondees of the newspaper ads. Responses to the questions are tabulated by both number and as a percentage of the total responses.

Discrepancies in the totals of the responses per question can be found. For example, it would appear that the total number of responses in question 10 should equal the total number of responses in portion (a) of question 9, but they do not. There are a few other discrepancies of this type. It was found by reviewing the original questionnaires that some had more than one answer checked off for certain questions, while others were not answered at all. Tabulation was made by considering number of responses to a specific question. No attempt was made to adjust responses to make totals agree.

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AMERICAN WIND ENERGY ASSOCIATION SITING STUDY QUESTIONNAIRE

1. Person completing this questionnaire:

Name:

Address:

City, State, Zip Code:

Telephone:

2. Location of windmill (if different from above):

Address:

City, State:

3. What did you use your windmill for?

	<u>RESPONSES</u>	<u>% OF RESPONSES</u>
a. water pumping	43	24%
b. radio	29	16%
c. home appliances	66	37%
d. farm equipment (electrical)	21	12%
e. farm equipment (mechanical)	2	1%
f. other (please specify)	18	10%

4. Who was the manufacturer?

a. Aeromotor	164	57%
b. Dempster	8	3%
c. Heller-Aller	2	1%
d. Halladay	0	0%
e. Bucknell	0	0%
f. Jacobs	49	17%
g. Wincharger	17	6%
h. Allied	0	0%

	<u>RESPONSES</u>	<u>% OF RESPONSES</u>
i. Dyna Technology	5	2%
j. Winco	0	0%
k. Aerodyne	0	0%
l. Ruralite	0	0%
m. Nelson	0	0%
n. Delco	0	0%
o. Air Electric	1	0%
p. Paris-Dunn	0	0%
q. Perkins	1	0%
r. Hebco	0	0%
s. Wind King	0	0%
t. Dunlite	25	9%
u. Elektro	4	1%
v. other (specify)	10	3%
w. don't remember	3	1%
5. When was your windmill installed?		
month _____ year _____		
6. Who installed it?		
a. yourself	71	52%
b. previous owner	17	12%
c. salesman or distributor	31	23%
d. manufacturer	4	3%
e. contractor	9	7%
f. other (please specify)	4	3%

		<u>RESPONSES</u>	<u>% OF RESPONSES</u>
7.	How high was the tower?		
a.	30 ft. or less	38	33%
b.	30 to 50 ft.	46	40%
c.	over 50 ft.	32	27%
d.	exactly _____ ft.	0	0%
8.	How was the tower height selected?		
a.	cost	22	15%
b.	that's all that was available	22	15%
c.	to clear obstructions	66	44%
d.	installers recommendation	2	1%
e.	manufacturers recommendation	21	14%
f.	other (please specify)	17	11%
9.	Did (do) you know the average wind speed in your area?		
a.	yes	79	59%
b.	no	54	41%
10.	If the answer is yes, how did you learn what the wind speed was?		
a.	from wind measurements	15	15%
b.	local wind data (for example, an airport)	58	59%
c.	from a neighbor	3	3%
d.	from the windmill installer or salesman	16	16%
e.	other (please specify)	7	7%
11.	What type of land was (is) the windmill located on?		
a.	hilly	50	35%

	<u>RESPONSES</u>	<u>% OF RESPONSES</u>
b. flat	53	36%
c. trees over 50 ft.	18	12%
d. trees under 50 ft.	18	12%
e. other (please specify)	7	5%
12. Did this influence where you put the windmill, and if so, how?		
13. Did the use of the energy produced influence windmill location, and if so, how?		
a. location of well	29	22%
b. where the power was to be used	69	52%
c. location of buildings	30	22%
d. other	6	4%
14. What other factors affected the location of the windmill?		
a. family wishes	19	20%
b. tower height	43	44%
c. cost	12	12%
d. legal considerations	5	5%
e. other	18	19%
15. How long was your windmill in operation?		
months _____ years _____		
16. How often did it require maintenance?		
a. more than once a year	33	34%
b. once a year or less	50	52%
c. never	13	14%

		<u>RESPONSES</u>	<u>% OF RESPONSES</u>
17.	What kind of maintenance did it require?		
a.	lubrication	69	59%
b.	replacement of parts	38	32%
c.	other	10	9%
18.	Were you satisfied with its operation?		
a.	produced as much power as expected	85	73%
b.	did not produce enough power	13	11%
c.	broke down often	16	14%
d.	other	2	2%
19.	Why did you stop using the windmill?		
a.	broke down in high winds (how strong do you think the winds were?)	3	2%
b.	broke in normal operation	7	6%
c.	was vandalized	0	0%
d.	no longer needed the power	31	26%
e.	still using it	67	56%
f.	other	12	10%

This space is provided for any additional comments you might have, or if there was not enough space to answer the question.

In answering questions 20-26, assume that you are considering purchasing a windmill at the present time.

20. What would you be willing to spend to determine the wind power available at your farm?

a.	less than \$10	34	28%
----	----------------	----	-----

		<u>RESPONSES</u>	<u>% OF RESPONSES</u>
b.	\$11 to \$50	27	22%
c.	\$51 to \$100	13	10%
d.	\$101 to \$250	4	3%
e.	\$251 to \$500	38	31%
f.	more than \$500	8	6%
21.	Where would you go first for information on windmills?		
a.	agricultural extension agent	14	10%
b.	farmers organization such as the Grange or Farm Bureau	6	5%
c.	farm machinery dealer	0	0%
d.	windmill dealer	77	58%
e.	other (please specify)	16	12%
f.	don't know	20	15%
22.	Where would you go first for information on the wind in your area?		
a.	closest airport	27	19%
b.	National Weather Service	50	34%
c.	windmill dealer	27	19%
d.	I have my own wind instruments	17	12%
e.	other (please specify)	10	7%
f.	don't know	13	9%
23.	Where would you go first for information on selection of a specific location for the windmill to gain the most wind power?		
a.	agricultural extension agent	9	7%
b.	farm organization	0	0%
c.	farm machinery or windmill dealer	62	47%

		<u>RESPONSES</u>	<u>% OF RESPONSES</u>
d.	National Weather Service	15	11%
e.	meteorologist	3	2%
f.	other (please specify)	11	9%
g.	don't know	17	13%
h.	would not select location on the basis of wind power	15	11%
24.	How much would you be willing to spend to identify the location which would provide the most wind power?		
a.	less than \$10	38	43%
b.	\$11 to \$50	33	37%
c.	\$51 to \$100	8	9%
d.	\$101 to \$250	7	8%
e.	\$251 to \$500	2	2%
f.	more than \$500	1	1%
25.	What size windmill would you want?		
a.	less than 5 kW	27	20%
b.	6 to 25 kW	66	49%
c.	26 to 50 kW	4	3%
d.	51 to 100 kW	8	6%
e.	more than 100 kW	6	4%
f.	don't know	24	18%
26.	What would you use a windmill for?		
a.	pump water	27	18%
b.	produce electricity for irrigation	7	5%
c.	produce electricity for home use	104	68%

		<u>RESPONSES</u>	<u>% OF RESPONSES</u>
	d. other (please specify)	12	8%
	e. don't know	2	1%
27.	Do you know of a dealer who sells windmills for pumping water?		
	a. yes	61	45%
	b. no	73	55%
28.	Do you know of a dealer who sells windmills for generating electrical power?		
	a. yes	80	61%
	b. no	51	39%
29.	Are you aware of any governmental programs supporting wind energy research and development?		
	a. yes	80	63%
	b. no	47	37%
30.	Would you be willing to participate in future studies regarding the use of wind energy?		
	a. yes	101	81%
	b. no	23	19%

This space is provided for any additional comments you might have, or if there was not enough space to answer questions 20-30.

APPENDIX C

PAST AND PRESENT WECS DISTRIBUTORS

Siting information was sought from past and present WECS distributors. The following presents a list of distributors contacted.

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PAST AND PRESENT WECS DISTRIBUTORS

Enertech
P. O. Box 420
Norwich, VT 05055

Walter Schoenball
45 Geneve 1211
Switzerland

American Wind Turbine
1016 E. Airport Rd.
Stillwater, OK 74074

Energy Alternatives
P. O. Box 233
Leverett, MA 01054

WinPower
1207 E. Avenue
Newton, IA 50208

Independent Energy Systems
6043 Sterrettania Rd.
Fairview, PA 16415

Windlite Alaska
Box 43
Anchorage, AK 99510

North Wind Power
Box 315
Warren, VT

Real Gas & Electric
P. O. Box A
Guerneville, CA 94306

Bob Dodge Automatic Power
Pennwalt Corp.
213 Hutcheson Street
Houston, TX 77023

Sencenbaugh Wind Electric
P. O. Box 11174
Palo Alto, CA 94306

Grumman Aerospace Corp.
4175 Veterans Memorial Hwy.
Ronkon Koma, NY 11779

Environmental Energies
Front Street
Copemish, MI 49625

Dominion Aluminum Fabrication
3570 Hawkestone Road
Mississauga, Ontario L5C 2V8

Bristol Aerospace LTD.
P. O. Box 874
Winnipeg, Manitoba
Canada R3C 2B4

Quirk's Victory Light Co.
33 Fairweather St.
Bellevue Hill, N.S.W.
Australia

ARCRAD Ltd.
150 Consumers Rd.
Willowdale, Ontario
Canada M2J 1T9

Enag S.A. Rue de Pont-l'Abbe
Quimper (Finistere)
France

H. J. Godwin Ltd.
Quenington Glous.
England GL7 5BX

Aerowatt S.A.
37 Rue Chanzy
75 - Paris 11^e France

J. Taylor
88 Hull Rd.
Woodmansey, East Yorkshire
England HU17 0TH

Dunlite Electrical
Div. of Pye Industries
21 Fromme Street
Adelaide 5000, Australia

Elektro G.m.b.H.
Winterthur
St. Gallerstrasse 27, Schweiz

Dyna Technology
Ecological Science corp.
Sioux City, IA 51102

Repair Works
Taiwan Power Company
61-Yuh Cheng St.
Na n-Kong, Taipei
Taiwan

Cytra, Inc.
Abrosio Bldg.
Buendia, Cor Bantista Makati
Phillipines

Westwind Development
108 Wedgewood Drive
Calgary, Alberta T3C 3G6

Par Industrial Contractors
P. O. Box 2328
Prince George, B.C.

Bugden & Associates
72 Broadview Avenue
Pointe Claire, P.Q.
Canada H9R 3Z4

Dempster Industries
711 S. 6
Beatrice, NB

Aermotor Div. of Braden Ind.
800 F. Dallas St.
Broken Arrow, OK 74012

Maschinenfabrik
Ludwig Bening
2847 Barnstorf
P. O. Box 171
Germany

Aetna Steel Industries
613 Roman Santos Bldg.
Plaza Coiti, Manila
Phillipines

The Wind Turbine Co. of Canada
George Fletcher Sales
Elmira, Ontario

International Aeradio
70 Don Park Rd., Unit 15
Markham, Ontario L3R 1G4

HPL Engineering
4 Cessar Avenue
Kemptville, Ontario
Canada K0G 1J0

APPENDIX D

SITING GUIDELINES

A review was made of siting guidelines offered by WECS distributors. Pertinent excerpts taken from owners' manuals of several distributors follow.

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SITING GUIDELINES

Jacobs Wind Electric

Jacobs Wind Electric systems were manufactured in Minnesota from 1931-1956. This company was the largest (dollar volume) manufacturer of wind machines of that period. Of the electrical generating machines surveyed, 46% were Jacobs. The diameter of these generators was a nominal 14 feet, and the electrical capacities ranged from 1,800 watts to 3,000 watts. It is thought that the success of the Jacobs marketing effort was due largely to his efforts to sell all the subsystems: storage, towers, appliances, etc., with his units.

The recommendations extracted from the owner's manual:

"The tower should be on the highest ground near the batteries. The tower should be of sufficient height to place the plant well above all surrounding trees and buildings by not less than 20 feet. Don't sacrifice a higher and better location just to save a few feet of wire. Remember, the plant must be installed where it will be above surrounding trees and buildings, because installing it 100 or 200 feet away will not eliminate the effect of obstructions on the wind currents."

Wind Power Manufacturing Company

Wind Power sold WinPower wind generators from 1932-1956. This company bought out Paris-Dunn and Ruralite (smaller wind electric manufacturers) in the 1930's and at its peak had 140 distributors. Twenty to twenty-five percent of their business was export, with Argentina being the largest importer. They

had special installation crews and their own finance company. They refused to finance customers who would not follow their recommendation and found that the greatest problem was convincing farmers to purchase a tower of sufficient height. The WinPower was 12 feet in diameter and had either 1250 watt or 1800 watt generators.

The recommendation on siting in the owner's manual was:

"The illustration (Figure D-I) shows why the tower must be fully 20 feet higher than all trees or obstructions within 500 feet. If not, the amount of power produced will be drastically reduced and little benefit will be secured in the lighter winds. The tower should be located on the highest ground available, preferably not over 200 feet from the batteries."

Allied Wind Electric

The exact dates of manufacture of the Allied Wind Electric Plants based in Spencer, Iowa, are not clear. They began in the early 1930's and operated until the late 1940's when they were purchased by Jacobs Wind Electric. Many of the design features of the Allied machines were later incorporated in Jacobs wind plants. These machines were a nominal 12 feet in diameter and were supplied with 1200 watt or 1600 watt generators.

Siting recommendations from the owner's manual read:

"Before starting to install your Allied Wind Electric Plant, recheck the location and height of your tower to be sure that when the tower is erected and the plant installed, it will not be less than 25 feet above all obstructions within a 500-1000 foot radius. This is important as the monthly output of your plant can be reduced 1/4 to as much as 1/2 its regular output

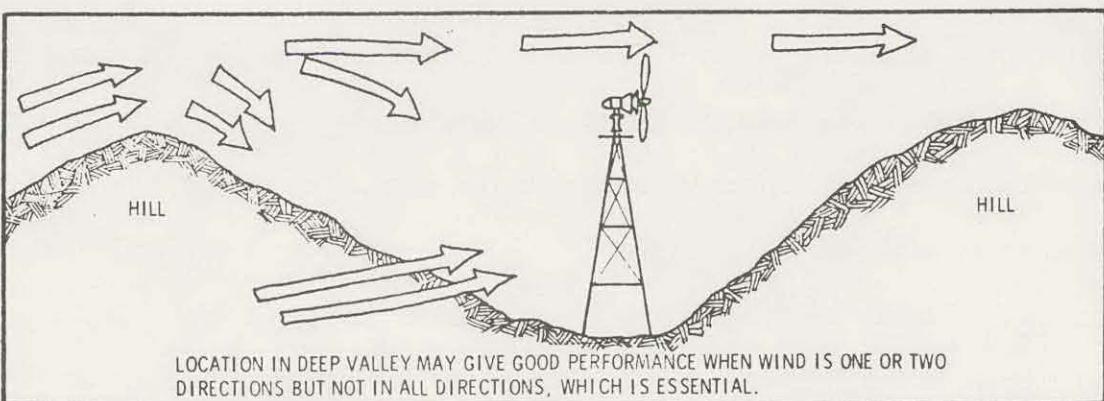
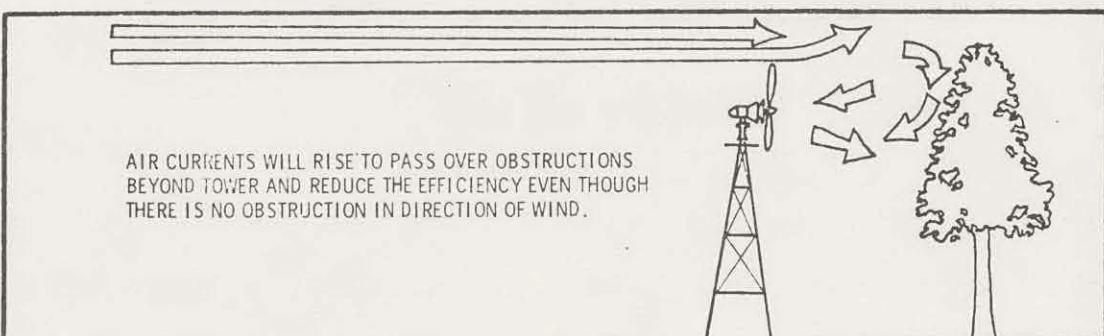
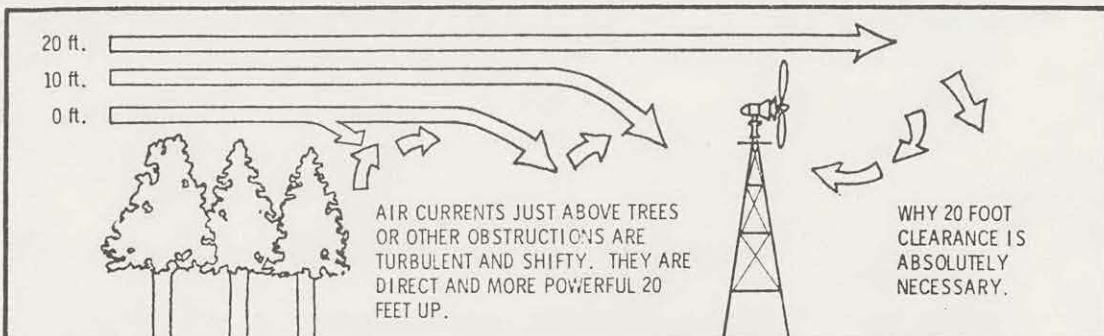
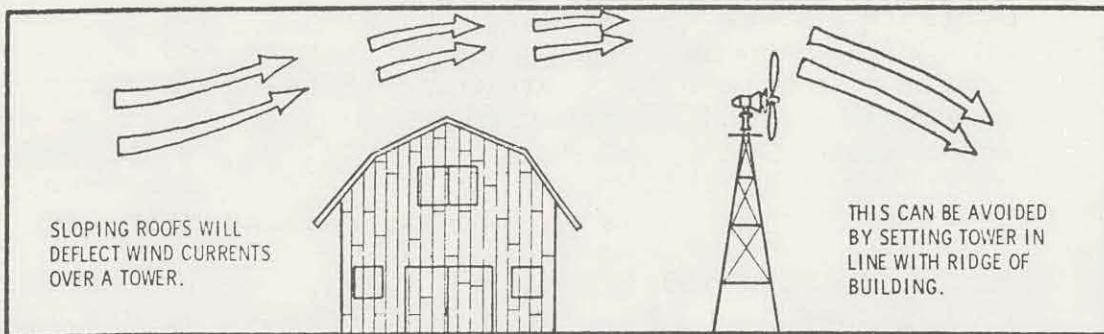


FIGURE D-I. Suggestions for the Proper Location of Your Tower (based on Winpower drawing)

if a row of trees or a big barn can deflect the wind currents before they reach your plant. The added cost of a higher tower will be many times repaid in the greater monthly output of your plant year after year. Remember, a wind electric plant depends on the wind for its power. Don't reduce its output and handicap its performance by failing to place it in a favorable location.

The standard distance for the tower location is 90 to 100 feet from the basement or batteries, but if higher ground and better wind currents can be secured at 150 to 200 feet, additional hook-up wire should be secured and the tower set at the better wind location."

Aerowatt, S.A.

Aerowatt machines are manufactured in France, primarily for remote power applications. The capacity of these units ranges from 24 watts to 4,100 watts. The emphasis in the design is on extreme durability in hostile environments. A primary application is navigational aids, where the traditional power supply is primary batteries that produce power at a cost of roughly \$20/kWh. Aerowatt has approximately 100 machines in service around the world and 20 in this country, primarily in the Gulf of Mexico. System size is based on annual energy production, with a 2 to 2.5 safety factor in terms of energy production capacity. In the Gulf of Mexico applications, annual average wind speeds are well known. Tower height is not an issue in that the machines are mounted on platforms well above the surface of the water, often 100 feet or more. Site analysis is not performed in these applications except for a prediction of annual energy production.

The siting guidelines that are given in the company manual:

"The operation of a wind generator is a function of the quality of the installation. Wind generators must be installed on supporting structures which insure clearance of neighboring obstacles and so place them in a purely laminar wind stream.

"For example, a cylindrical obstacle will create whirlwinds with a rotation axis parallel to the cylinder, and which will exist up to a distance equal to ten times the obstacle diameter.

"Another example is found on the top of cliffs, or the summit of slopes where rising air currents produce whirlwinds with a horizontal axis and which can reach high altitudes.

"When testing a site, a qualitative method consists in bringing in one way or another, ribbons 1 or 2 meters long, at the height at which the wind generator will be installed. The way the ribbons react will rapidly show whether the airflow is laminar or boisterous.

"Aerowatt can only guarantee its equipment if they have been correctly installed. For this purpose, send Aerowatt a survey of the ground area chosen for the wind generator site over a radius of 100 to 200 meters. Aerowatt will then let the user know if it agrees with the location."

Dunlite

The Dunlite, manufactured in Australia, has been the largest selling wind machine in recent years. Approximately 23% of the installations surveyed were Dunlites. The reason for this lies primarily in the comparatively low cost. These machines are a nominal 12 feet in diameter and have a 2,000 watt electrical capacity.

The siting recommendations given in the owner's manual:

"Examine the proposed site to make sure that the plant will receive the maximum force of the prevailing wind for the particular area.

"Most of the criticism of unsatisfactory operation of a wind driven plant is due to their installation in an unsuitable position or low towers.

"Maximum efficiency is only possible where the plant operates in a clear and steady airstream.

It is essential that the plant is at least 15-20 feet clear of all obstacles (buildings, trees, etc.) and the tower is sufficient height to reduce ground disturbance - a minimum of 40 feet is recommended.

"Make sure that the plant is at least placed between the direction of prevailing winds and any buildings, etc. Any object higher than the plant will cause a disturbance in air flow for approximately 300 yards in front of the plant and 50-100 yards behind the plant.

"In hilly areas it is better to place the plant 200-300 yards away from the building housing the batteries and control equipment if a better wind location is thus obtained.

"The steadier the air flow in which the plant is operating, the higher the average output, and the less strain is placed on the plant due to the frequent changes in wind direction."

Winco

Winco, a division of Dyna Technology in Sioux City, Iowa, manufactures a small wind system used for battery charging applications. This machine is 6 feet in diameter and produces 200 watts. Winco is the only manufacturer in operation today from the pre-REA period.

Their siting recommendations, taken from the owner's manual:

"For good performance, it is necessary that the wind driven generator be mounted where the wind from all directions has an uninterrupted flow to the propeller. Any obstruction such as trees, hills, or buildings, even though they are somewhat lower than the charger, will set up rough air currents that seriously decrease the generator output. These 'rough' air currents have lost a large part of their power and are continually shifting from one direction to another and also shift upward or downward. They also tend to increase

vibration. All these factors should be considered in selecting a satisfactory location for the charger. The higher the charger the better, for the air currents are smoother and steadier further from the ground. For good operation, the charger should be mounted at least 15 feet above any obstructions within 400 feet.

"If the charger cannot be mounted any higher than surrounding obstructions, it should be more than 400 feet from these obstructions. If the charger cannot be mounted as high as the surrounding obstructions, it should be placed at least 800 feet from these obstructions. Neither of these installations are recommended in preference to an installation in which the charger is mounted considerably above the obstruction. They are merely substitutes for the better type installation.

"Another important fact to remember is that the charger should be mounted as close to the battery as possible. The further the charger is mounted from the battery, the greater the loss of energy in the wires. Since 100 feet is the maximum recommended distance between the charger and the battery and since the battery will ordinarily be kept in the house, one of the methods suggested in this book should be followed to mount the charger close to the house and up high enough to receive an unobstructed sweep of the wind. Remember that if the charger is placed further from the battery, the wiring cost will be greater for two reasons: 1) the wire must be longer, and 2) the wire must be of larger diameter.

"In case there is no way of installing the charger near the house and above surrounding obstructions, it is possible to install the charger at a distance from the house in some unobstructed spot. For greater convenience it may be mounted on a two or four wheeled cart and moved from one location to another depending on the direction of the wind. Unless a very heavy cart is used, the tower should always be guyed to prevent it from blowing over in strong winds. The battery in this case will have to be taken to the wind generating plant for charging.

"The service and satisfaction of a wind driven generator depends so much on the proper location that it cannot be emphasized too strongly that to make a good installation, it is absolutely necessary that the charger not be shielded from the wind in any direction.

"The top illustration (Figure D-II) shows a type of installation superior to either of the other two for two reasons: First, the charger is mounted at least 15 feet higher than any obstructions within 400 feet as recommended and second, the charger is mounted close to the house on a pole so that no vibration and rumble is heard in the house. The first illustration is the ideal type, and although a little more difficult, the extra time and money spent on this type of installation will more than pay for itself in the quiet and efficient service it renders.

"In the second illustration, the installation is better than the one shown at the bottom of the page because the trees are not as high and the 10 foot tower has been used instead of the 5 foot tower. This type of installation will give better performance at all times than the one illustrated below because the air currents will be smoother and steadier.

"Note in the bottom diagram the surrounding trees are higher than the propeller. With high winds this type of installation will produce some current, but do not expect good results with this type of installation. The air currents will be rough and very unsteady, and the generator output will be low."

NorthWind Power Company

NorthWind Power Company is one of the major wind machine distributors currently in operation in this country. They sell reconditioned Jacobs machines and a more recent, small (1 kW) machine manufactured by Aero Power. They also offer site surveys which consist of recording the wind velocity distribution and attempting to develop a correlation with existing Weather Bureau data. They sell a variety of anemometry hardware including a pilot tube-type sensor, wind-run recorders, a wind velocity distribution recorder (10 registers, 1 minute average), and strip chart recording anemometers.

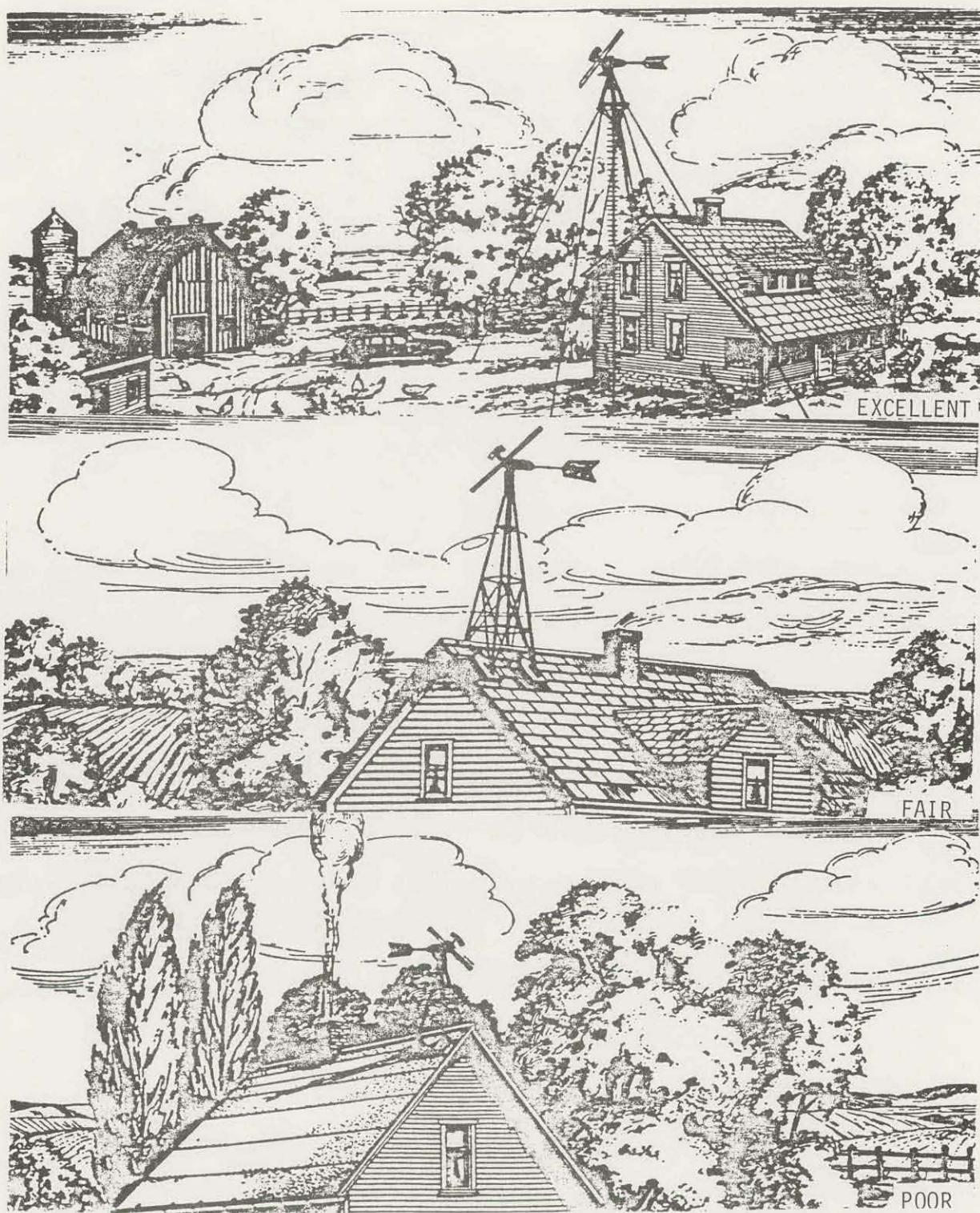


FIGURE D-II. Types of Charger Locations
(from WINCO)

In their catalogue, they offer the following comments on siting:

"The selection of the correct tower height for the wind system is a very important consideration. Improper tower height or location can significantly limit the wind generator output. The rule of thumb to determine correct tower height is that the tower should be 20 feet above any obstructions within 500 feet. Wind speeds at 40 feet above the ground can be as much as 50% stronger than ground winds. Since the power from the wind is proportional to the cube of the velocity, correct tower height can significantly affect the number of kilowatt hours a given system will produce."

(They also published a drawing similar to WinPower: Figure D-III.)

Enertech, Inc.

Another major distributor of wind driven generators in this country is Enertech. They distribute the Swiss made Elektro (the largest Elektro is 20 feet in diameter with a 10 kW electrical capacity) and the Dunlite, previously mentioned. In response to requests for information on the use of wind energy, they have prepared a paper entitled:

"Planning a Wind Energy Conversion System: Basic Principles, Components of a System, Estimating Wind Availability, Estimating Power Requirements."

The section from that publication reads:

"Regardless of what winds are dominant, care must be taken to select a site where there will be the least obstruction to free wind flow, and particularly the free wind flow of the 10 to 25 mph winds. Large obstructions such as high hills are likely to cause 'wind shadow' reducing the total wind availability. Smaller obstructions such as houses, trees, and small hills or sharply rising hills behind the site are likely to cause either interference or turbulence, impeding the usable wind flow.

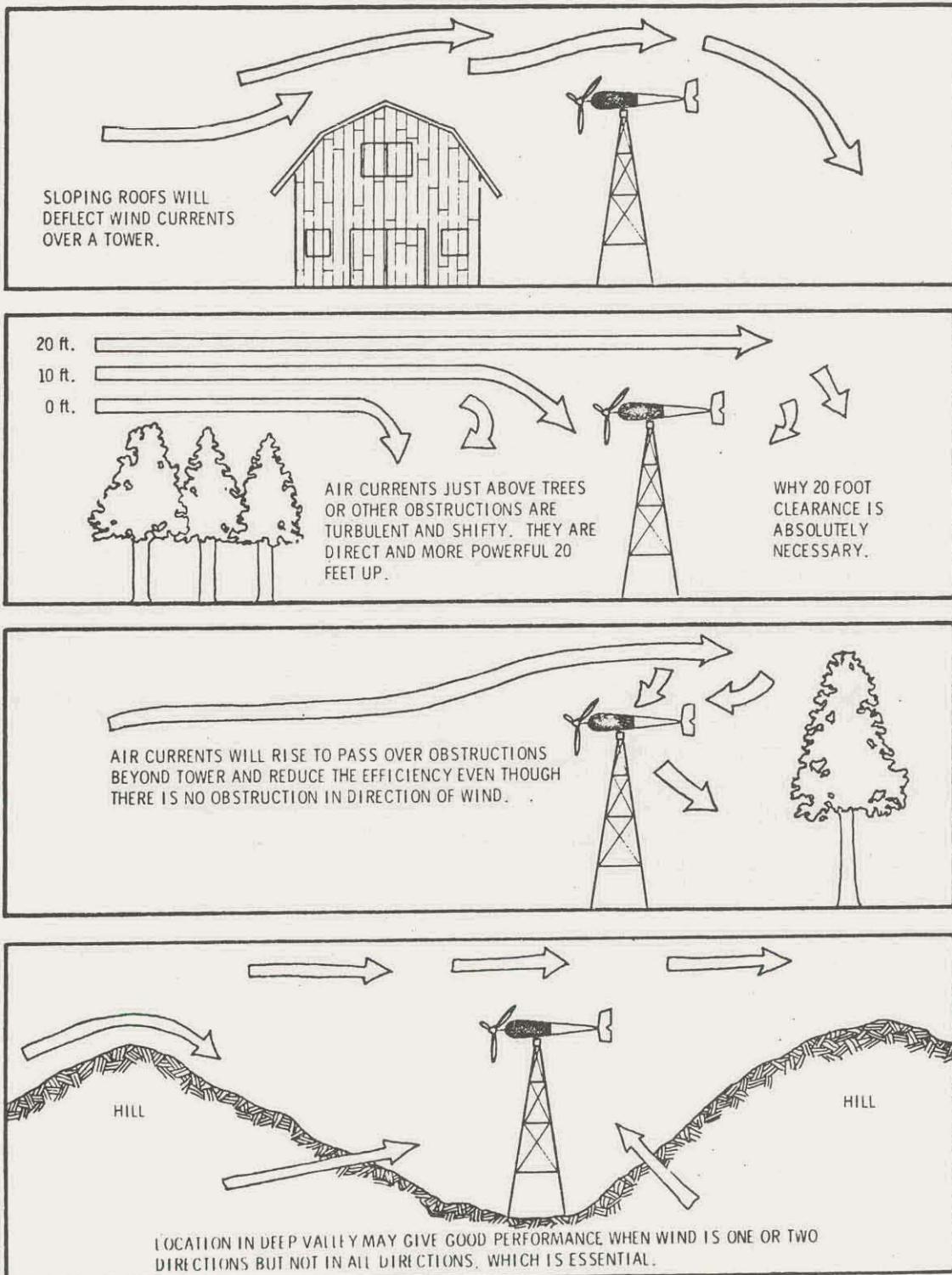


FIGURE D-III. Selection of Tower Heights
(based on Northwind drawing)

"The ideal tower site is also close to the point where the power will be stored and consumed, minimizing the investment in heavy gauge, low resistance wire running from the tower to the control panel and batteries. Next to your house or shop is ideal (if the tower is high enough); within 50 to 200 feet is fine; beyond 250 feet you will increase your cost substantially.

"After locating your tower the next step is to establish the minimum tower height for the particular site. Ground friction can reduce the wind speed by 50%, so the generator should always be mounted at least 30 feet and preferably 40 feet above the ground. It should also be mounted at least 20 feet and preferably 30 feet above any trees or buildings within 400 feet that might either block the winds or cause turbulence. Turbulence not only reduces wind availability but may prove hazardous to the generator assembly by exerting unequal wind pressure on the individual blades. Remember that the obstacles behind the tower can create the same problems of turbulence as obstacles in the front. Remember too, that the cost of an additional 10 feet or even 30 feet of tower height is minor compared to the increased power you will obtain from the additional wind.

"One simple method for detecting turbulence at your tower site is to put up a pole with one or two ribbon streamers. In a good breeze if the ribbons fly out straight and steady, the wind flow is smooth. If you see a lot of flapping, there is turbulence at that level, and you should either locate your wind generator higher or look for a better site."

APPENDIX E

WIND ENERGY BIBLIOGRAPHY

A listing of the literature related to wind energy, wind energy conversion, and wind energy conversion systems which was reviewed is presented in the following pages. The listings of significant papers and reports have been annotated.

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1. Academy of Sciences (USSR), "METHODS OF ANALYSIS OF WIND POWER POTENTIAL TO FIVE REGIONAL CHARACTERISTICS", 1963, 190 p.

2. Ailleret, P., "WIND ENERGY: ITS VALUE AND CHOICE OF SITE FOR EXPLOITATION", Review Gen. Elec., Paris, Vol. 55, pp. 103-108, March 1946.

The problem of wind power utilization is discussed, including determination of wind power per square meter obtained yearly from surfaces subjected to wind action, and systematic prospecting for favorable sites using a simple anemometric device which calculates wind speed with the aid of a special electric meter. A description is given of a program for site selection which will make it possible to determine the energy which can be produced by the wind engine used. (Technology Application Center, TAC, review)

3. Ailleret, P., "LA RECHERCHE DES SITES QUI POURRAIENT CONVENIR A UNE UTILISATION DE L'ENERGIE DU VENT", La Meteorologie, pp. 145-152, April-June, 1948.

To assess wind power possibilities, a wind energy survey is necessary. A wind energy meter developed for this purpose, the choice of site areas, and the first results of the survey are described. (TAC review)

4. Alaka, M.A., editor, "THE AIRFLOW OVER MOUNTAINS", Tech. Note N. 34, WMO-No. 98 TP.43, Secretariate of the World Meteorological Organization, Geneva, Switzerland, 1961.

5. Anderson, S.R., "A COMPARISON OF MONTHLY WIND MILEAGE FROM TYPE 45B AND U2A ANEMOMETERS", Department of Transport, Meteorological Office, Ottawa, Canada, 1956.

6. Andreyev, I.D., "WIND GUSTINESS WITHIN AN HOURLY INTERVAL", Voprosy Vetroenergetiki (questions of wind energy production), Moscow, an SSSR publication, 1959.

7. Anufriev, A.F., Supriaga, I.A.A., "WIND ENERGY - ENERGETIC RESOURCES OF THE REPUBLIC KOMI, ASSR", Acad. of Sciences of the U.S.S.R., Filiale, Komi. Pp. 28-31, Moscow, 1963.

8. Argand, "MEASUREMENT OF THE CHARACTERISTIC PARAMETERS OF WIND POWER FOR THE SELECTION OF FAVOURABLE SITES FOR WIND-DRIVEN GENERATORS", Proceedings of the U.N. Conference on New Sources of Energy, W/35, Rome, August 1961, Vol. 7, U.N., New York, 1964.

Time constants of Robinson, Papillon, and Ailleret anemometers considered as well as the Best-Romani type. Variation among these suggest that standards be established for presenting wind power data. World-wide wind power potential is discussed, a standard anemometer height above 20 meters is suggested, and projections with respect to the direction of wind power development in Europe and in developing countries are offered. (SB)

9. Aujesky, L., "COMPUTATION OF QUADRATIC AND CUBIC MEAN VALUES OF WIND VELOCITY FOR THE ESTIMATION OF AVAILABLE WIND POWER", Idojaras 55 (3/4): 79-81, March/April 1951.

Representations of wind conditions by average values of wind velocity are not sufficient to determine wind power at a given location. Theoretically wind power is proportional to the third power of wind and velocity. The usable power from synchronous generators is proportional to the square of the wind speed. Therefore it is necessary to compute quadratic and cubic means of wind velocity.

10. Ballester, Miguel, "SPECULATIVE METHODS IN WIND SURVEYING", Proceedings of the U.N. Conference on New Sources of Energy, W/7, Rome, August, 1961, Vol. 7, U.N., New York, 1964.

Assumes the site can be selected and is not predetermined by the load center. Discusses field procedures and statistical procedure for comparing sites. Three sites in Spain were instrumented and statistically compared. The author suggests that site analysis is in its exploratory stage and that a mixture of subjective evaluation and rigorous scientific method must by necessity be used in site selection. (SB)

11. Barasoain, J.A. and Fontan, L., "PROSPECTING FOR WIND POWER WITH A VIEW TO ITS UTILIZATION", Proceedings of the U.N. Conference on New Sources of Energy, W/16, Rome, August, 1961, Vol. 7, United Nations, New York, 1964.

This paper analyzes methods used in compiling, from the data furnished by meteorological services and the results obtained from specific wind prospecting networks, statistics for use in studies of wind power utilization.

Pertinent results based on all available data are given in relationship to mainland Spain, and the most important wind basins are outlined and described. A general study of the winds prevailing in the region which embraces the Canary Islands and the coast-line of the Sahara desert is included and includes results from forty stations in this area and subsequent analyses of the wind. (SB)

12. Bergey, Karl H., "WIND POWER DEMONSTRATION AND SITING PROBLEMS", Wind Energy Conversion Systems, Workshop Proceedings, Washington, D.C., June, 1973, NSF/RA/W-73-006, pp. 41-45.

Technical and economic feasibility studies on a small windmill to provide overnight charging for an electrically driven car. Optimization of a windmill/storage system requires detailed wind velocity information which permits rational siting of wind power system stations. (TAC review)

13. Bettingnies, Christian, "POTENTIAL OF WIND POWER UTILIZATION IN THE ARCTIC ENVIRONMENT", Brace Research Institute, No. DT-10, 1970, McGill University, Montreal, Canada.

14. Briggs, J., "AIRFLOW AROUND A MODEL OF THE ROCK OF GIBRALTAR", Meteorological Office Scientific Paper No. 18, 1968.

15. Bitte, Jurgen and Frost, Walter, "ATMOSPHERIC FLOWS OVER A FENCE", report in preparation under NASA contract.

16. Blake, Stephen R., "SITE ANALYSES FOR LOCATING WIND ENERGY CONVERSION SYSTEMS", unpublished master's thesis, Department of Geography-Meteorology, University of Kansas, Lawrence, 1974.

17. Blake, Stephen R. "INTERIM REPORT TO KARL J. BEA ASSOCIATES", Brace Research Institute, McGill University, Nov., 1974.

An exploratory site analysis for a fifty foot diameter wind turbine system proposed for Saskatchewan by Ultramar Oil Company of the United Kingdom. The report provides access to the workings of the Department of Transport, Meteorological Branch - Environment Canada and the procedures for accessing wind data from them. (SB)

18. Blake, Stephen R., SITE ANALYSIS HANDBOOK FOR WIND ENERGY SYSTEMS, Appropriate Technology Group, Route 1, Box 93-A, Oskaloosa, Kansas, to be released in early 1977.

This handbook reviews the history of siting practices and synthesizes the information available today. Using this information as a starting point, procedures are offered for determining the optimum location for a family/small business size (less than 10 meter diameter) wind electric system in an area. Necessary equipment is described for measuring the power in the wind with examples provided for reference. Also considered are total system economics including system life, initial and recurring costs, present status of interfacing systems with power utility grids, maintainance schedules, and various methods for examining cost/benefits of a system. (SB)

19. Brevoort, M.J. and Jayner, U.T., "EXPERIMENTAL INVESTIGATIONS OF THE ROBINSON-TYPE CUP ANEMOMETER", Langley Memorial Aeronautical Laboratory, National Advisory Committee for Aeronautics, Langley Field, Va., October, 1934.

20. Buhl, S.M., "OPERATING EXPERIENCE OF WIND POWER PLANTS", World Power Conference, Belgrade, 1957, 11th Sectional Meeting, Section B4, Paper 37, 11 pages, 1957.

In order to investigate the possibilities of producing electricity by means of wind power in connection with networks for the public supply, the Southeast Zealand Electricity Co. Ltd. (Called "SEAS" in Denmark) since 1947 has had wind energy measured in various places in Denmark, and after certain other preliminary investigations, a 12 KW wind power plant has been erected. A second one, of 45 KW was built in 1952. Since the end of 1953, both plants have been working regularly in connection with the SEAS network. An account is given of the daily, monthly, and annual outputs of the plants as well as of the way in which their output fits in with consumption of power from the SEAS network. This grid is normally supplied with energy from several thermal power plants in Zealand which are run in parallel with power stations in the southern part of Sweden. A third experimental wind power plant, of 200 KW is being constructed in Denmark. (Review from Tech. Hag., Eindhoven, October, 1974).

21. Cambilargiu, "WIND MEASUREMENTS IN SOUTHERN ARGENTINA AND REMARKS ON WIND AND SOLAR ENERGY IN THAT COUNTRY", Proceedings of the U.N. Conference on New Sources of Energy, W/10, Vol.7, Rome, August, 1961, United Nations, New York, 1964.

22. Casper, R.H., "VARIATIONS OF WIND VELOCITY IN GERMANY FOR WIND POWER GENERATION", ASCE translation 118: 463-488, 1953.
23. Changery, M., "INITIAL WIND ENERGY DATA ASSESSMENT STUDY", Second Workshop on WECS, June 9-11, 1975, 10.00, MITRE pp. 326-35.

This paper reports on the meterological data available from the National Climatic Center, Asheville, N.C. It discusses some of the problems in using this data to determine the siting of wind energy systems. Some suggestions are made on how to improve data acquisition methods by the use of uniform anemometer tower heights and the standardization of frequency of measurement. Figures included.

24. Christaller, H., "NUTZBARMACHUNG DE WINDENERGIE", Elektrizitaetswirtschaft 50 (11): 320-322, November 1951.

Translation: Linguistic Systems, Inc., Cambridge, Mass. N 74-16756, NTIS, Feb. 1974, 12 p.

25. Christaller, H., "INSTRUMENTS AVAILABLE IN GERMANY FOR MEASURING WIND POWER", from Windpower Working Party, Organization for European Economic Co-operation, pp. 189-193, printed by H.M.S.O., London, U.K., 1953.
26. Christaller, H., "WIND VELOCITY AND ECONOMIC ROTATIONAL SPEED OF WINDMILLS", Windpower Working Party, Organization for European Economic Co-operation, pp. 285-293, printed by H.M.S.O., London, U.K., 1953.
27. Cisman, A and N. V. Botan, "CONSIDERATIONS ON THE POSSIBILITY OF UTILIZING WIND ENERGY IN ROUMANIA", Rev. Stiint. 34: 35-42, January-June 1948. (In Roumanian)

Wind observations in the Balkans are recorded in order to show the possibility of installing wind turbines.
28. Cisman, A. and N. V. Botan, "SECOND PRELIMINARY REPORT ON THE POSSIBILITIES OF UTILIZING WIND ENERGY IN ROUMAINIA". Bull Inst. Rech. Tech Roumanie 3 (1): 95-99., 1948.

Continuation of previous study.

29. Cormier, Rene V., "AN ANNOTATED LISTING - TALL TOWERS INSTRUMENTED FOR WIND OBSERVATIONS", Technical Report 73-0179, Air Force Cambridge Research Laboratory, L.G. Hanscom Field, Bedford, Mass., March, 1973.
30. Corotis, R.B., "STOCHASTIC MODELING OF SITE WIND CHARACTERISTICS", Second Workshop on WECS, June 9-11 1975, \$10.00, MITRE. pp. 341-43.

An analytical approach consisting of a multi-dimensional stochastic model of wind characteristics involving spatial and temporal correlation.

31. Court, Dr. Arnold, "WIND SHEAR EXTREMES", a presentation appearing in Initial Wind Energy Data Assessment Study by M. Changery, NSF-RA-N-75-020, May 1975.

32. Crawford, K.C., Hudson, H.R., "BEHAVIOR OF WINDS IN THE LOWEST 1500 FEET IN CENTRAL OKLAHOMA", June 1966-May 1967, National Severe Storms Lab., Norman, Okla., 68 pp., August 1970.

Two towers are used in this test. Wind and temperature sensors are placed at different heights on the towers. Variability of wind speed and direction is investigated using transition matrices.

33. Cudbird, B.S.V., "DIURNAL AVERAGES OF WIND, ATMOSPHERIC PRESSURE, AND TEMPERATURE AT SELECTED CANADIAN STATIONS", Department of Transport, Meteorological Branch, Ottawa, Canada, Sept. 1964.

34. Davenport, A.G., "RATIONALE FOR DETERMINING DESIGN WIND VELOCITIES", ASCE Proceedings (Structures Division), Vol. 86, 1960.

35. Davenport, A.G., "THE SPECTRUM OF HORIZONTAL GUSTINESS NEAR THE GROUND IN HIGH WINDS", Quarterly Journal of Royal Meteorological Society, Vol. 87, No. 372, p. 194-211, 1961.

36. Davidson, Ben, "SITES FOR WIND POWER INSTALLATIONS", World Meteorological Organization Technical Note No. 63, Geneva, Switzerland, 1974.

The most comprehensive overview of siting techniques and information available, Davidson considers all aspects

of siting. The paper is aimed at large installations and assumes that the availability of wind power is the major factor in determining the location of a wind power installation. He concludes that sites must be analyzed individually and that no rules of thumb with respect to topographic influences on wind or to wind profiles may be applied out of hand. This paper synthesizes the work of other research and field work and is not based on the authors research in the field. (SB)

37. Deacon, E.L., "VERTICAL PROFILES OF MEAN WIND IN THE SURFACE LAYERS OF THE ATMOSPHERE", Geophysical Memoirs, Meteorological Office, London, 91, England.
38. Doraiswamy, I.V. and S.K. Banerji, "WIND DATA FOR WINDMILLS", India Meteorological Department, New Delhi, India, Scientific Notes VI (63): 1948.
39. Duchon, Claude, "WIND VELOCITY AS MODIFIED BY GEOMORPHOLOGY, Second Annual Conference on WECS, June 9-11, 1975. pp. 367-371. MITRE. \$10.00.
40. Eldridge, Frank (editor), PROCEEDINGS OF THE SECOND WORKSHOP ON WIND ENERGY CONVERSION SYSTEMS, held in Washington, D.C., June 9-11, 1975, sponsored by NSF and ERDA, published by the Mitre Corporation, McLean, Va., 1975.

This broad based workshop brought together a broad range of individuals working in wind systems. Many of the presentations touch briefly on the siting of wind machines. Section VII of the workshop, "Wind Characteristics," includes these presentations: "WIND CLIMATOLOGY", by Jack W. Reed, Sandia Labs; "INITIAL WIND ENERGY DATA ASSESSMENT STUDY", by Michael Changery, NOAA/NCC; "WIND CHARACTERISTICS AND WIND POWER GENERATION: A THREE YEAR METEOROLOGICAL PROGRAM IN SWEDEN", by Lars Olsson, Olof Holme, and Roland Krieg, SAAB-SCANIA AB; "STOCHASTIC MODELLING OF SITE WIND CHARACTERISTICS", by Ross B. Corotis, Northwestern University; "SITES FOR WIND-POWER INSTALLATIONS" Robert N. Meroney, Colorado State University; "LOCATING AREAS OF HIGH WIND ENERGY POTENTIAL BY ERTS OBSERVATIONS OF AEOLIAN GEOMORPHOLOGY", by J. Marwitz and R. Marrs, University of Wyoming; "A NEW WIND ENERGY SITE SELECTION METHODOLOGY", by B.E. Freeman, Science Applications, Inc.; "ANNUAL POWER OUTPUT POTENTIAL FOR 100-KW AND 1 MW AEROGENERATORS" by C.G. Justus, Georgia Institute of Technology; "WIND VELOCITY AS MODIFIED BY GEOMORPHOLOGY", by Claude E. Duchon, University of Oklahoma; "A TECHNIQUE FOR OPTIMALLY LOCATING WIND ENERGY SYSTEMS" by

Fred M. Vukovich and Andrew Clayton, Research Triangle Institute. These presentations are not reviewed herein as these workshop proceedings are currently a standard reference. (SB)

41. Frenkiel, J., "WIND FLOW OVER HILLS, IN RELATION TO WIND POWER UTILIZATION", Proceedings of the U.N. Conference on New Sources of Energy, W/33, Rome, August, 1961, United Nations, New York, 1964, Vol. 7.

Starting in 1953, Frenkiel undertook the study of wind power potential in Israel. He instrumented two types of peaks: 1) A mountain ridge athwart the prevailing wind direction with a steep leeward side; 2) An isolated peak in a valley in the general direction of prevailing winds. He concludes that criteria for a good wind power site emerges from his investigations, namely that the mean wind vertical gradient for the height interval from 10 to 40 m above the ground be 1) less than five per cent for optimal sites 2) five to ten per cent for very good sites 3) ten to fifteen per cent for good sites 4) a mean power law exponent of no greater than .14 for fair sites. Further, he concludes that the slope of the hill determines this mean wind vertical gradient and relates to the above conditions as follows: 1) results from slopes of 1 in 3½; 2) results from smooth, regular slopes of about 1 in 6; 3) results from smooth regular shallow slopes of about 1 in 10, or fairly rough but regular slopes of about 1 in 6; 4) results from a variety of topographic conditions such as low-level coastal sites, smooth aerodynamically very shallow sloped of about 1 in 20, very rough aerodynamically but regular steep slopes of about 1 in 6, and very steep slopes with gradual slope gradient within a radius of about 50 m from the hilltop. These statements of Frenkiel's are rare in the literature of topographic effects on wind power sites. (SB)

42. Frenkiel, J., "WIND PROFILES OVER HILLS (IN RELATION TO WIND POWER UTILIZATION)", Quarterly Journal Royal Meteorological Society, Vol. 87, 1961.

This article is a condensed version of the presentation given at the U.N. Conference in Rome. (SB)

43. Frost, Walter, "REVIEW OF DATA AND PREDICTION TECHNIQUES FOR WIND PROFILES AROUND MANMADE SURFACE OBSTRUCTIONS", AGARG Conference Proceeding No. 140, Flight in Turbulence, Woburn Abbey, Bedfordshire, England, May 1973.

44. Frost, Walter, "WIND FIELDS OVER TERRAIN IRREGULARITIES", a presentation in Initial Wind Energy Data Assessment Study, by M. Changry, NSF-RA-N-75-020, May 1975.

Considers wind flow with respect to flat terrain, various surface discontinuities, hills and mountains, valleys, and buildings. Numerous graphic images aid in explaining various phenomenon. (SB)

45. Garrison, J.A. and Cermak, J.E., "SAN BRUNO MOUNTAIN WIND INVESTIGATION - A WIND TUNNEL MODEL STUDY", Colorado State University, 1968.

46. Gartsman, L.B., "PRINCIPLES FOR CALCULATING LIMITING VALUES OF ENERGY PRODUCING PARAMETERS OF THE WIND STRUCTURE", TASHKENT, IZD. An. Vz. SSR, 1963.

47. Geiger, Rudolf, THE CLIMATE NEAR THE GROUND, Harvard University Press, Cambridge, Massachusetts, 1965.

48. Giblett, M.A., "THE STRUCTURE OF WIND OVER LEVEL COUNTRY", Geophys. Mem. Met. Off., London, Vol. 6, No. 54, 1932.

49. Gibson, L.R., "WIND ANALYSIS IN RELATION TO THE DEVELOPMENT OF WINDPOWER", Oklahoma State University, 147 pp. 1969.

50. Glann, H.R., "A METHOD FOR PREDICTING SURFACE WINDS", Weather Bureau, Silver Springs, Md., Systems Development Office, 21 pp., March 1970.

A method to operationally forecast surface winds. Several regression models are applied to available data. Indications are that this method produces short range forecasts of wind that are as accurate or more accurate than official aviation terminal forecasts.

51. Golding, E.W., and Stodhart, A.H., "THE POTENTIALITIES OF WINDPOWER FOR ELECTRICITY GENERATION", (with special reference to small scale operation), Electrical Research Association, Tech. Report WT 16, 26 pp., 1949.

52. Golding, E.W., "STUDIES OF WIND BEHAVIOR AND INVESTIGATION OF SUITABLE SITES FOR WIND DRIVEN PLANTS, NEW SOURCES OF ENERGY", Proceeding of UN Conference in Rome, Vol. 7 (gr/6w), pp. 3-8.

53. Golding, E.W., "LARGE SCALE GENERATION OF ELECTRICITY BY WINDPOWER", Preliminary Report, Elect. Res. Assoc. Tech. Report c/T101, 1949.

Studies of winds at several sites in Great Britain.

54. Golding, E.W. and Stodhart, A.H., "THE SELECTION AND CHARACTERISTICS OF WIND POWER SITES", Electrical Research Association, Tech. Report C/T 108, 32 pp., Leatherhead, Surrey, U.K., 1952.

The methods used in and the results obtained from a wind survey in the United Kingdom are described in detail. (TAC review)

55. Golding, E.W., "MEASUREMENT OF WIND VELOCITY AND POWER", Windpower Working Party, Organization for European Economic Co-operation, printed by H.M.S.O., London, U.K., 1953, pp. 193-207.

56. Golding, E.W., THE GENERATION OF ELECTRICITY BY WIND POWER, Philosophical Library, Inc., New York, 1956.

57. Golding, E.W., "METHODS OF ASSESSING THE POTENTIALITIES OF WIND POWER ON DIFFERENT SCALES OF UTILIZATION", Solar and Aeolian Energy, Proceedings of the International Seminar held at Sounion, Greece, 1961, Plenum Press, New York, pp. 152-157.

58. Griffith, H. L., Panofsky, H.A., and Van der Hoven, I., "POWER SPECTRUM ANALYSIS OVER LARGE RANGES OF FREQUENCY", Journal of Meteorology, Vol. 13, 1956, pp. 279-282.

59. Hagne, L.J. and Skidmore, E.L., "TURBULENT VELOCITY FLUCTUATIONS AND VERTICAL FLOW AS Affected BY WINDBREAK POROSITY", Transactions of the ASAE, Vol. 14, No. 4, July-August, 1971.

60. Haldane, T.G.N., "THE LOCATION AND OPERATION OF WIND DRIVEN PLANT", Windpower Working Party, Organization for European Economic Co-operation, pp. 147-149, printed by H.M.S.O., London, U.K., 1953.

61. Harris, R.I., "ON THE SPECTRUM AND AUTO-CORRELATION FUNCTION OF GUSTINESS IN HIGH WINDS", Electrical Research Association Publication #5273, Surrey, England, 1968.

62. Heronemus, W.E., "POWER FROM THE OFFSHORE WINDS", Eighth Annual Conference and Exposition on Applications of Marine Technology to Human Needs, pp. 435-66, September 11-13, 1972.
63. Hewson, E.W., "WIND POWER POTENTIAL IN SELECTED AREAS OF OREGON", Report No. PUD 73-1, March 1973; No. PUD 74-2A, August 1974; No. PUD 74-2B, August 1974; No. PUD 75-3, August 1976; No. PUD 76-4, June 1976; Oregon State University, Department of Atmospheric Sciences.

The research which these reports describe was undertaken in 1971 by Oregon State University and four Oregon Peoples Utility Districts. Previous wind data was considered and new stations were established in locations of potentially high wind power. Various student projects were integrated into these reports including wind tunnel modeling and testing of landforms, and the use of smoke plume rockets for determining wind profiles. These studies are inspiring models for what individual states, utility companies, and universities can do in assessing wind power potential. (SB)

64. Heywood, G.S.P., "WIND STRUCTURE NEAR THE GROUND AND ITS RELATION TO TEMPERATURE GRADIENT", Quarterly Journal Royal Meteorological Society, Vol. 57, p. 433, 1931.
65. Hoff, W., "THEORY OF THE IDEAL WIND POWER MACHINE", Z Flugiechn. II: 223, 1920.
66. Huang, Chin-Hua and Nickerson, "STRATIFIED FLOW OVER NON-UNIFORM SURFACE CONDITIONS: MIXING LENGTH MODEL", Journal of Boundary Layer Meteorology, January 1974.
67. Hutter, U., "THE USE OF WIND ENERGY FOR GENERATING ELECTRIC CURRENT IN WESTERN GERMANY", National Committee of the German Federal Republic, World Power Conference, Rio de Janeiro, 1954 (Titulo 4, Assunto 4.1).
68. Hutter, U., "PLANNING AND BALANCING OF ENERGY OF SMALL-OUTPUT WIND POWER PLANT", Proceedings of the New Delhi Symposium on Wind and Solar Energy, UNESCO, Paris, 1956.

69. Hutter, U., "THE EFFECT OF WIND FLUCTUATIONS ON THE CHOICE OF SPEED FOR WIND-POWER PLANTS", Zietschrift fur Elektrotechnik 1: 117-122, 1948 and 2: 10-15, 1949.

70. Hyson, P., "CUP ANEMOMETER RESPONSE TO FLUCTUATING WIND SPEEDS", Vol. 2, No. 5, Journal of Applied Meteorology, pp. 843-848, August 1972.

71. Iyer, V.D., "WIND DATA FOR WINDMILLS". Ind. Met. Dep. Sci. Notes VI: 63, 1935.

72. Jensen, Martin, "WIND MEASUREMENTS", Proceedings of the U.N. Conference on New Sources of Energy, W/14, Rome, August 1961, Vol. 7, United Nations, New York, 1964.

This presentation describes wind velocity measurements made in Denmark, at the location of the Gedser windgenerator and at two other locations. A power distribution meter which describes the wind velocity in six intervals was used and is described. (SB)

73. Jespersen, Anders (editor), International Symposium on Molinology, Denmark, May 1969, Lyngby, Danske Mollers Venner, Brede Vaerk, 1971.

74. Justus, C.G., "WIND DATA COLLECTION AND ASSESSMENT" in Wind Energy Data Assessment Study, by M. Changery, NSF-RA-N-75-020, May 1975.

75. Justus, C.G., "ANNUAL POWER OUTPUT POTENTIAL FOR 100 KW AND 1 MW AEROGENERATORS", Second Annual Workshop on WECS, June 9-11 1975, pp. 360-66.

This report presents 1) a method for computing actual expected output power from a wind generator given the observed wind speed distribution, 2) results of application of this method in the form of aerogenerator plant factor (ratio of average power output to rated power) for the Continental U.S. The plant factors that were evaluated have the characteristics of the NASA 100 KW plumbrook machine and the design characteristics of the 1 MW aerogenerator. The Weibull was used because of its two parameters.

76. Juul, J., Supplement to the Report on the Results Achieved with SEAS Experiment Al Mill, Kanner (Leo)Associates, Redwood City California, 40 pp. 1974

77. Juul, J., "INVESTIGATION OF THE POSSIBILITIES OF UTILIZATION OF WIND POWER", Elektroteknikeren, Vol 45, pp. 607-635, Oct. 22, 1949 (available through the Electrical Research Association Leatherhead, Surrey, U.K., as translation IB1025).

Climatic conditions of Denmark are briefly surveyed and results of a series of measurements on wind velocity at different points and at different heights are tabulated with data on annual kw-hr generation obtainable with various types of wind motor. The velocity-meter and motors are described. Annual variation of kw-hr obtainable is shown in graphs. The economics of wind-power utilization are discussed in detail, with special regard to local conditions. (Review by Tech. Hag., Eindhoven)

78. Juul, J., "MEASURING WIND VELOCITIES AT VARYING HEIGHTS ABOVE GROUND", Windpower Working Party, Organization for European Economic Co-operation, printed by H.M.S.O., London, U.K., 1953.

79. Karmishin, A.V., "WIND AND ITS UTILIZATION", Moscow, Gos. IZD-VO Tekhniko Report, Litary, 1951, 62 p.

Discusses several characteristics of the wind.

80. Kleinhenz, F., "WEIGHT AND COST COMPARISON FOR LARGE WIND POWER PLANTS OF DIFFERENT HEIGHTS FOR THE SAME WHEEL DIAMETER", Stahibau No. 17/18: 1943.

81. Klevantsova, V.A., Bortkovskii, L., and Preobrazhenskii, L.Yu., "METHODS OF GRADIENT MEASUREMENT AT SEA", translated by A. Nurklik, Meteorological Translations, No. 14, pp. 55-66, Canada Department of Transport, Meteorological Branch, Ottawa, Canada, 1968.

82. Krasovskiy, N.V., "WIND ENERGY-PRODUCING RESOURCES OF THE USSR AND PROSPECTS FOR THEIR UTILIZATION". Atlas Energoresursou SSSR L. Moscow, Russia, Energoizolat Publications, 1936.

83. Lange, Karl O., "SOME ASPECTS OF SITE SELECTION FOR WIND POWER PLANTS ON MOUNTAINOUS TERRAIN", Proceedings of the U.N. Conference on New Sources of Energy, W/28, Rome, August 1961, Vol. 7, United Nations, New York, 1964.

Tradeoffs between height of tower and costs are considered. Speed-up of wind is desirable but not predictable from previous aerodynamic research. Subjective evaluations considered. (SB)

84. Lantagne, Michel, "WIND POWER STUDY OF THE ST. LAWRENCE LOWLANDS, SURVEY OF AVAILABLE WIND DATA", Brace Research Institute, McGill University, Montreal, Quebec, Canada, Internal Report No. I-52, October 1968.

85. Lee, L., "SAMPLE RATE REQUIRED TO ESTIMATE ENERGY IN WIND SPEED RECORD". Unpublished Report, Oklahoma State University, 1967.

86. Lettau, H.H. and Davidson, Ben, EXPLORING THE ATMOSPHERE'S FIRST MILE, Volume 2, Pergamon Press, New York, 201 pages.

87. Lumley, J.L. and Panofsky, THE STRUCTURE OF ATMOSPHERIC TURBULANCE, Interscience Publishers, New York, 1964, 231 pp.

88. Marwitz, J., and Marrs, R., "LOCATING AREAS OF HIGH WIND ENERGY POTENTIAL BY THE ERTS OBSERVATIONS OF AEOLIAN GEOMORPHOLOGY". Second Annual Workshop on WECS, June 9-11, 1975, \$10.00, MITRE. pp. 253-55.

This paper describes the research methods used to determine whether ERTS Observations can be used to locate favorable sites for WECS. The study is being conducted in the Great Basin of the Western U. S.

89. Masterson, G.E., "LABORATORY EXPERIMENTS ON THE TECHNIQUE OF SITE SELECTION USING AN ELECTROLYTIC TANK", Windpower Working Party, Organization for European Economic Co-operation, pp. 145-147, printed by H.M.S.O., London, U.K., 1953.

90. Meier, R.C., "CONCEPT ANALYSES OF LARGE WIND GENERATOR SYSTEMS", Paper presented at the 31st Annual National Forum of the American Helicopter Society, Pre-print S-997, May 1977.

91. Merchant, D.A., STOCHASTIC MODEL OF WIND GUSTS, unpublished Ph.D. Thesis, Stanford University, 1965.

92. Meroney, R.N. and Cermak, J.E., "WIND TUNNEL MODELING OF FLOW AND DIFFUSION OVER SAN NICOLAS ISLAND, CALIFORNIA", Colorado State University, 1967.

93. Meroney, R.N. and Chaudhry, F.H., "WIND TUNNEL SITE ANALYSIS OF DOW CHEMICAL FACILITY AT ROCKY FLATS, COLORADO", Colorado State University, 1972.

100. Nilakantan, P., "SOME CONSIDERATIONS AFFECTING THE CHOICE OF AREAS FOR PRELIMINARY WIND POWER SURVEYS IN INDIA", from the Proceedings of the New Delhi Symposium on Wind and Solar Energy, UNESCO, Paris, 1956, pp. 38-41.

101. Nilakantan, P. and Varadarajan, R., "STUDIES ON THE UTILIZATION OF WIND POWER IN INDIA", Bangalore National Aeronautical Laboratory, Bangalore, India, 1962.

102. Oopt, A.H., Rasmusson, E.M., "ATMOSPHERIC CIRCULATION STATISTICS", Environmental Research Labs., Princeton, N.J. Geophysical Fluid Dynamics Lab., 335 pp. 1971.

103. Ower, E., THE MEASUREMENT OF AIRFLOW, Chapman and Hall, Ltd., 1949.

104. Pagon, Watters, "WIND VELOCITY IN RELATION TO HEIGHT ABOVE GROUND", Engineering News-Record, Vol. 114, pp. 742-745, 1935.

105. Panofsky, H.A., "STATISTICAL PROPERTIES OF THE VERTICAL FLUX AND KINETIC ENERGY AT 100M.", Penna. State Min. Dev. Sci. Rep., No. 21, 1953.

106. Panofsky, H.A., and McCormick, R.A., "PROPERTIES OF SPECTRA OF ATMOSPHERIC TURBULANCE AT 100 METERS", Quart. Journal of Royal Met. Soc., Vol 80, 1954.

107. Perlat, "WIND MEASUREMENT IN METEOROLOGY", (summary), Proceedings of the U.N. Conference on New Sources of Energy, W/13, Rome, Vol. 7, August 1961, United Nations, New York, 1964.

The presentation indicates the way in which the wind is measured at meteorological stations and suggests standards for measurement procedures and equipment. (SB)

108. Peronaci, F., "DETERMINATION OF WIND ENERGY FOR THE PURPOSE OF ITS UTILIZATION BY WIND MACHINES", Annali di geofisica 3 (2): 223-230, April 1950.

The wind characteristics in several zones in Calabria are studied with wind machine installations in mind.

94. Milakanton, P., "SOME CONSIDERATIONS AFFECTING THE CHOICE OF AREAS FOR PRELIMINARY WIND POWER SURVEYS IN INDIA, WIND AND SOLAR ENERGY", Proceedings of the New Delhi Symposium, UNESCO, Paris, pp. 38-41.

95. Monin, A.S. and Obukhov, A.M., BASIC LAWS OF TURBULENT MIXING IN THE GROUND LAYER OF THE ATMOSPHERE, translated from Akademia Nauk, SSSR, Leningrad, Geofizicheskii Institute, Trudy, Vol. 151, No. 24, pp. 163-187, 1954 (reference from Aeroenvironment).

96. Morgans, W.R., "RELATION BETWEEN GROUND CONTOURS, ATMOSPHERIC TURBULANCE, WIND SPEED, AND DIRECTION", Aeronautical Research Committee Reports and Memoranda No. 1456 (T.3 198), December 1931 (reference from Brace Research Institute card catalogue, this is most likely a Canadian government publication).

97. Mullet, L.F., "SURVEYING FOR WIND POWER IN AUSTRALIA", Ins. Engineers, Australia - J, 29 (3): pp. 69-73, March 1957.

98. National Aeronautical Laboratory, Bangalore, India, series entitled "HOURLY WIND SPEEDS AT (the following cities) FROM THE POINT OF VIEW OF WIND POWER UTILIZATION":

Jamshedpur, No. TN-WP-34-64	Kadaikanal, No. TN-WP-17-62
Gopalpur, No. TN-WP-27-63	Vishakhapatnam
Allahabad, No. TN-WP-22-63	No. TN-WP-21-63
Bhopal, No. TN-WP-23-63	Bombey (Santa Cruz)
Calcutta (Dum Dum), No. TN-WP-28-63	No. TN-WP-19-62
Jaipur, No. TN-WP-25-68	Jodhpur, No. TN-WP-29-63
Gaya, No. TN-WP-32-63	Lucknow, No. TN-WP-26-63
Amritsar, No. TN-WP-24-63	New Delhi, No. TN-WP-31-63
Ahmedabad, No. TN-WP-18-62	Poona, No. TN-WP-16-62

99. Nelson, Vaughn and Gilmore, Earl, "POTENTIAL FOR WIND GENERATED POWER IN TEXAS", State of Texas Governor's Energy Advisory Council, Report NT/8, October 1974.

This comprehensive report reviews the currently available hardware (1974), current research efforts, and the general context of wind energy. With this groundwork put forth, the wind data available from the National Weather Service for Texas is analyzed and wind power potential for the state is derived. The panhandle of Texas is perhaps the area of the highest wind power potential in the country and this report is aimed at laying the groundwork for development of this resource within the state. A good model for other states. (SB)

109. Petterssen, Sverre, "SOME ASPECTS OF WIND PROFILES", Proceedings of the U.N. Conference on New Sources of Energy, W/26, Rome, Vol. 7, August 1961, United Nations, New York, 1964.

The profile descriptions of Prandtl, Deacon, Palm, Monin and Obukov, Ellison, and Swinbank are considered and Petterssen concludes that the models by Monin and Obukhov, Ellison, and Palm deserve particular attention for wind power sites. Present knowledge on sites on ridges is felt to be inadequate and little evidence indicates that speed-up factors exist over the mountains in new England from his work with the Smith-Putnam project. (SB)

110. Pigge, H., "ANNUAL AVAILABILITY AND SPEED CHARACTERISTICS OF THE WIND FOR WIND POWER UTILIZATION", Elektrizitätswirtschaft, Vol. 54, Oct. 1955, pp. 704-709.

Optimum design methods for wind driven electrical generating plants are presented, based on yearly permanent wind level lines for selected erection sites. Wind conditions at any site are divided by five classes, of which only a few can be exploited by a given system. General purpose design curves are given. (Review by TAC)

111. Plate, E.J. and Lin, Chi W., "THE VELOCITY FIELD DOWNSTREAM FROM A TWO-DIMENSIONAL MODEL HILL", Fluid Dynamics and Diffusion Lab, Colorado State University, 1965.

112. Prakasa Rao, M.S., Rada Krishnan, S.R., "A STUDY OF THE HOURLY WIND SPEEDS AT KODAKANAI FROM THE POINT OF VIEW OF WIND POWER UTILIZATION", National Aeronautical Lab., Bangalore (India) 24 pp., Dec. 1964.

113. Priestly, C.H.B., TURBULENT TRANSFER IN THE LOWER ATMOSPHERE, University of Chicago Press, 1959.

114. Putnam, P.C., POWER FROM THE WIND, Van Nostrand, Inc., New York, 1948.

The classic work on the Grandpa Knob project. A detailed explanation of the assumptions and procedures used in siting the machine is given. It is determined that no a priori statements can be made with respect to speed-up over ridges from their experience. Correlations between limited data sets of wind velocity at several sites and wind velocities at nearby long established weather stations are considered. The machine produced from ten to thirty per cent of the power that had been anticipated from the

site survey performed and it is concluded that had instruments been installed at the proposed site for sufficient time prior to machine installation, the particular site would not have been used. (SB)

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116. Ramakrishnan, K.P. and Venkiteshwaran, S.P., "WIND POWER RESOURCES OF INDIA WITH PARTICULAR REFERENCE TO WIND DISTRIBUTION", Proceedings of the U.N. Conference on New Sources of Energy, Vol. 7, W/19, Rome, August 1961, United Nations, New York, 1964.

Using wind run data from nearly 150 recording stations and hourly wind speeds for nearly 25 stations, the wind power potential of India is considered by the authors. Velocity duration curves of eight stations are derived. The use of water pumping equipment at a selected station is also included. (SB)
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119. Rao, D.V.L.N., Narasimhawswamy, K.N., Radhakrishnan, S.R., "A STUDY OF HOURLY WIND SPEEDS AT JAGDALPUR AND JAMSHPUR FROM THE POINT OF VIEW OF WIND POWER UTILIZATION", National Aeronautical Lab. Bangalore (India), 26 pp. Jan. 1964.
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121. Reed, Jack, "WINDPOWER CLIMATOLOGY", Weatherwise, pp. 237-242, December 1974.

122. Reed, Jack W., "WINDPOWER CLIMATOLOGY OF THE UNITED STATES", Sandia Labs, Albuquerque, N.M., SAND74-0348, June 1975

All suitable data in the National Climatic Center archives, for 758 stations, have been analysed for monthly, seasonal, and annual average wind power. Results have been assembled in maps with equal power (isodyn) contours to show geographic regions most suitable for wind power exploitation. An Appendix contains an almanac of all these wind speed distributions and power data tabulations, ordered by state and region and suitable for referencing.

Wind speed versus height above ground relationships were examined with upper air climatologies at 85 kPa and 70 kPa pressure-altitude levels and certain micrometeorological research towers. The one-seventh-law wind profile law appears adequate from this. (As abstracted by the publication)

The stations presented are not described by anemometer heights and there has been no attempt to level the data to a standard anemometer height or to a standard atmospheric pressure. (SB)

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125. Rosenbrock, H.H., "THE DESIGN AND DEVELOPMENT OF THREE NEW TYPES OF GUST ANEMOMETER", Elect. Res. Associates Technical Report C/T106.1951. 37 pp.

126. Santorini, P., "A DIRECT METHOD OF MEASUREMENT AT WINDPOWER", Windpower Working Party, Organization for European Economic Co-operation, printed by H.M.S.O., Londson, U.K., 1953.

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The errors in cup anemometers due to their non-linearity of indication and the influence of atmospheric turbulence is discussed. Windmill anemometers not affected by turbulence are described and the over-estimation of wind

speed by both cup and windmill type anemometers is considered. Site selection for wind measurement is considered as well as instrumentation technique.

The presentation is constructed to point up the difficulties in comparing wind data taken with different equipment and in changing equipment at an existing station. (SB)

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136. Shellard, H.S., "EXTREM WIND SPEEDS IN THE COMMONWEALTH OF THE CARIBBEAN", Caribbean Meteorological Institute, 1970.

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Considers the flow of air in level, open country and concludes that the one-seventh-power law is a sufficiently close approximation to the variation of 5 minute wind velocity with height up to 1,000 feet above which a constant velocity is justified. Gust factors are proportional to the inverse ratio of heights raised to the power 0.0625. (Abstract from the article.)

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Two years of data have been processed to show relationships between wind gustiness and other meteorological parameters. The gustiness classification used at Brookhaven National Laboratory is defined by the range and appearance of the horizontal wind direction trace. The seasonal and diurnal variations are presented. Gustiness is closely related to lapse rate and solar radiation, while its association with wind speed and Sutton's index of turbulence is not as distinct. (Abstract from the article.)

140. Sissenwine, N., Tattelman, P., Grantham, D., Gringorten, I., "EXTREME WIND SPEEDS, GUSTINESS AND VARIATIONS WITH HEIGHT FOR MIL-STD 210B", Air Force Cambridge Research Labs. (LKI), 29 August 1973. 72 pp.

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This paper gives velocity versus height measurements on a TV tower in the Philadelphia area. The results show an increase in velocity of 100-200 per cent from 12 meters up to 270 meters above the hilltop. The paper also gives some turbulence factors and estimates the roughness height Z to be from 2 to 3 depending on wind direction. (Review from Hewson, PUD 73-1)

142. Sohn, Chang Wook, "WIND POWER PLANT SITE SELECTION", thesis in Mechanical Engineering, Texas Tech. University, May 1975.

A test of Putnam's ratio method using data from number of sites. Data from Reese Air Force Base and Lubbock, Texas is analysed (13 miles apart) and the error is found to be roughly 25 per cent. (Review from a conversation with Vaughn Nelson)

143. Soliman, K.H., "STUDY OF WIND BEHAVIOR AND INVESTIGATION OF SUITABLE SITES FOR WIND-DRIVEN PLANTS", Proceedings of U.N. Conference on New Sources of Energy, Vol. 7, W/4, Rome, August 1961, United Nations, 1964.

A detailed study of the wind on the coast of Egypt looks at monthly and diurnal variations in wind velocities and concludes that four synoptic observations at six hour intervals provides a good indication of wind power potential. (SB)

144. Stein, D.R., "THE COLLECTION AND EVALUATION OF STATISTICS ON ELECTRICITY GENERATION FROM WIND POWER STATIONS", Elektrizitätsswirtschaft 50: 279-285, October 1951; 325-329, November 1951. Translation: NTIS N 74-25618 1974, 23 p. and N 74-22708, 16 p.

Detailed statistical evaluation of from 43-88 wind power plants in Denmark from 1941-1944. Plants are divided according to type and size. Comparison of actual and theoretical utilization of energy from the wind is discussed.

145. Stodhart, A.H., "THE GENERAL REQUIREMENTS OF SITES FOR WIND-DRIVEN GENERATORS", Windpower Working Party, Organization for European Economic Co-operation, pp. 181-185, printed by H.M.S.O., London, U.K., 1953.

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147. Stodhart, A.H., "SELECTION OF TOWER HEIGHT FOR A WIND-DRIVEN PLANT", in Initial Wind Energy Data Study, by M. Changery, NSF-RA-N-75-020, May 1975, pp. 122-125.

Stodhart considers tower height with respect to the exponent of the power law and offers parameters for evaluating these for self-supporting structures. Tower height

is concluded to be a function of the cost/benefit ratio which in turn is directly influenced by the exponent. With exponents less than roughly .1, increasing tower heights is not beneficial financially. With exponents greater than .1, tower height increases can be justified in certain conditions. (SB)

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- 149. Sulzer, P., "A DIRECT METHOD FOR SELECTING WIND TURBINE GENERATOR; PARAMETERS FOR MAXIMUM ENERGY OUTPUT", Sulzer Associates, Stevensville, Md., 21666. 5 pp.
- 150. Sutton, O.G., "THE LOGARITHMIC LAW OF WIND STRUCTURE NEAR THE GROUND", Quart. J. Roy. Met. Soc., Vol. 63, pp. 105-107, London, 1937.
- 151. Syverson, Charles D. and Symons, John G., "INFORMATION AND PLANNING MANUAL FOR WIND DRIVEN ELECTRIC POWER SYSTEMS", Wind Power, Box 233, Mankato, Minn., 56001
- 152. Tagg, J.R., "METHODS OF MEASUREMENT USED IN WIND VELOCITY SURVEYS", Tech. Paper No. 24, pp. 185-188, Wind Power Working Party, Organization for European Economic Co-operation, printed by H.M.S.O., London, U.K., 1953.
- 153. Tagg, J.R., "WIND DATA RELATED TO THE GENERATION OF ELECTRICITY BY WIND POWER", Electrical Research Association, Tech. Report C/T 115, Surrey, England, 1957.

Purpose of this wind survey of Great Britain and Ireland was to assess potentialities of wind as sources of electrical energy; results of measurements analyzed; section dealing with results of wind measurements in other countries included to help in assessing potentialities of wind power overseas, and to compare different wind regimes. (TAC review)

154. Tagg, J.R., "WIND MEASUREMENTS IN RELATION TO THE DEVELOPMENT OF WIND POWER", Proceedings of the U.N. Conference on New Sources of Energy, Vol. 7, W/12, Rome, August 1961, United Nations, New York, 1964.

The paper reviews the various types of anemometers and examines their suitability for different kinds of wind measurement. An outline scheme is given for the investigation of wind flow over an area. Comments are made on the installation of anemometers. The use which can be made of existing wind data is considered in relation to the wind measurements actually carried out. Two specially developed wind speed recorders are illustrated and described. A method is shown for comparing the value of one site with another in terms of specific output. Mention is made of several methods of recording extreme wind speeds for design purposes. (Tagg's summary of paper.)

155. Tattelman, Paul, and Gringorten, Irving, "ESTIMATED GLAZE ICE AND WIND LOADS AT THE EARTH'S SURFACE FOR THE CONTIGUOUS UNITED STATES", Technical report 73-0646, Air Force Cambridge Research Laboratory, L.G. Hanscom Field, Bedford, Mass., October 1973.

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Presentations from this conference on siting for wind systems are listed and reviewed individually herein.

160. United Nations Educational, Scientific, and Cultural Organization, WIND AND SOLAR ENERGY, proceedings of the New Delhi symposium, Paris, 1956.

161. Van der Hoven, I., "POWER SPECTRUM OF HORIZONTAL WIND SPEED IN THE FREQUENCY RANGE FROM 0.0007 to 900 CYCLES PER HOUR", Journal of Meteorology, Vol. 14, pp. 160-164, 1957.

162. Venters, J., "THE ORKNEY WINDMILL AND WIND POWER IN SCOTLAND", Engineer, Vol. 189, pp. 106-108, 1950.
Discusses the considerations and progress of research work which led to the choice of the site. The development of other sites in Scotland is probable. (Review from Tech. Hag. Eindhoven)

163. Vukovich, F.M. and Clayton, Andrew, "A TECHNIQUE FOR OPTIMALLY LOCATING WIND ENERGY SYSTEMS", Second Annual Conference on Wind Energy Systems, June 9-11, 1975, pp. 372-374. MITRE.
This paper discusses a proposed research project that will provide a technique for determining favorable windy locations. The study will be done in the St. Louis area but will be general enough to apply to other regions. A statistical model will be developed for relating wind speed and direction at each site to those at a synoptic weather station. Evaluation will be made by comparing the observed wind distributions to their corresponding predicted distributions.

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A shortage of coal in Germany forces the use of wind power. This is a summary of wind characteristics in Germany and how a wind machine should be designed with these characteristics in mind.

173. World Meteorological Organization, "SURVEY OF EXISTING WIND OBSERVATIONAL INFORMATION", Proceedings of the United Nations Conference on New Sources of Energy, Vol. 7, Rome, August 1961, United Nations, New York, 1964.
Review of the wind data available in the world. Concludes that existing wind observations are not always available in an ideal form for use in wind energy calculations. There is a trend seen for meteorological services to calculate the frequency distribution of wind data instead of means. Data storage and retrieval systems in computers are seen as major advances in this area.

174. Zbrozek, J.K., "ATMOSPHERIC GUSTS, PRESENT STATE OF THE ART AND FURTHER RESEARCH", Journal of the Royal Aeronautical Society, Vol. 69, pp. 27-45, Jan. 1965.

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