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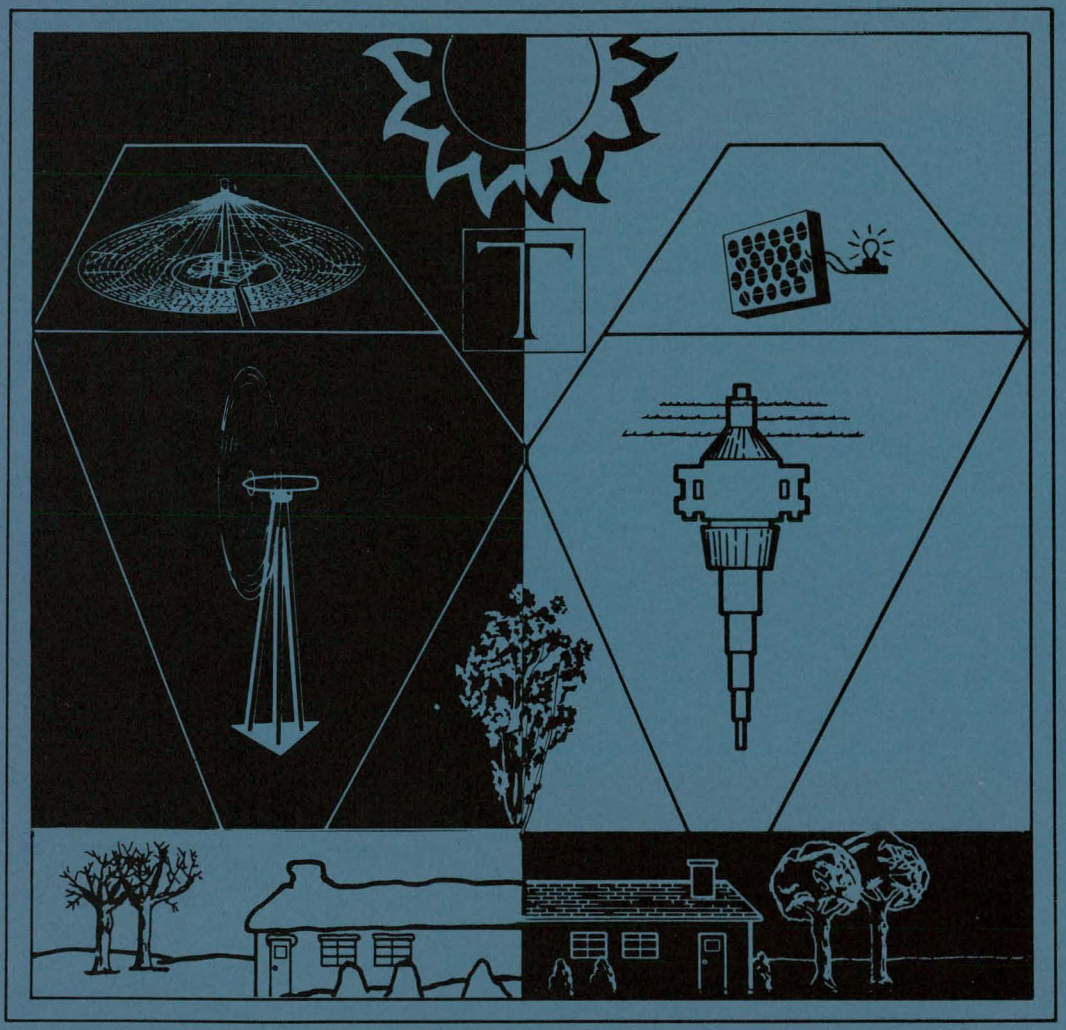
FEDERAL WIND ENERGY PROGRAM



PROGRAM SUMMARY JANUARY 1978

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U.S. DEPARTMENT OF ENERGY

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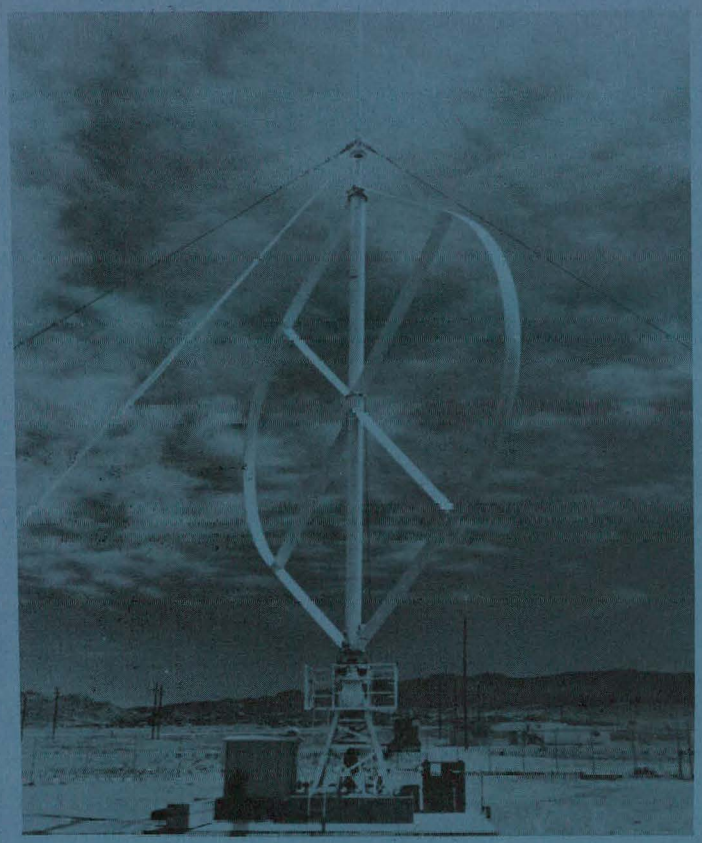

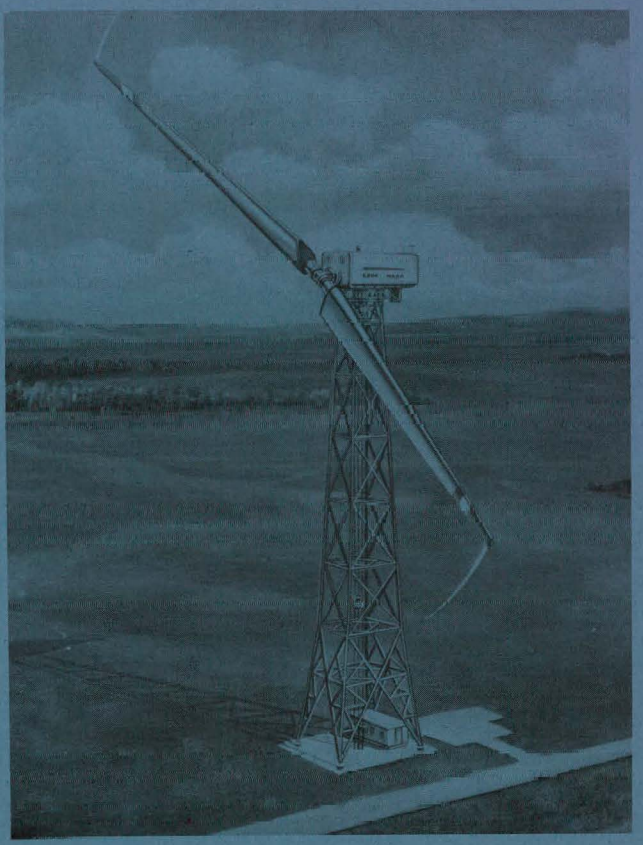

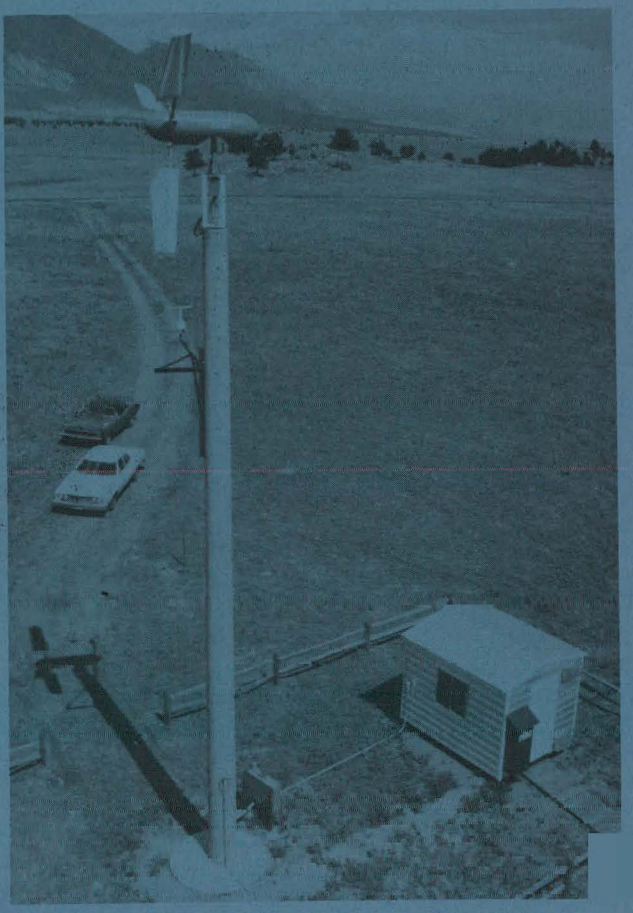

1) Upper left: 17-meter Darrieus vertical-axis wind turbine at Sandia Laboratories; 2) upper right: MOD–1 2 megawatt wind turbine to be field-tested at Boone, North Carolina; 3) left: proposed design of MOD–2 300-foot diameter wind turbine; 4) right: small commercial unit being tested at DOE Rocky Flats Plant.

FEDERAL WIND ENERGY PROGRAM

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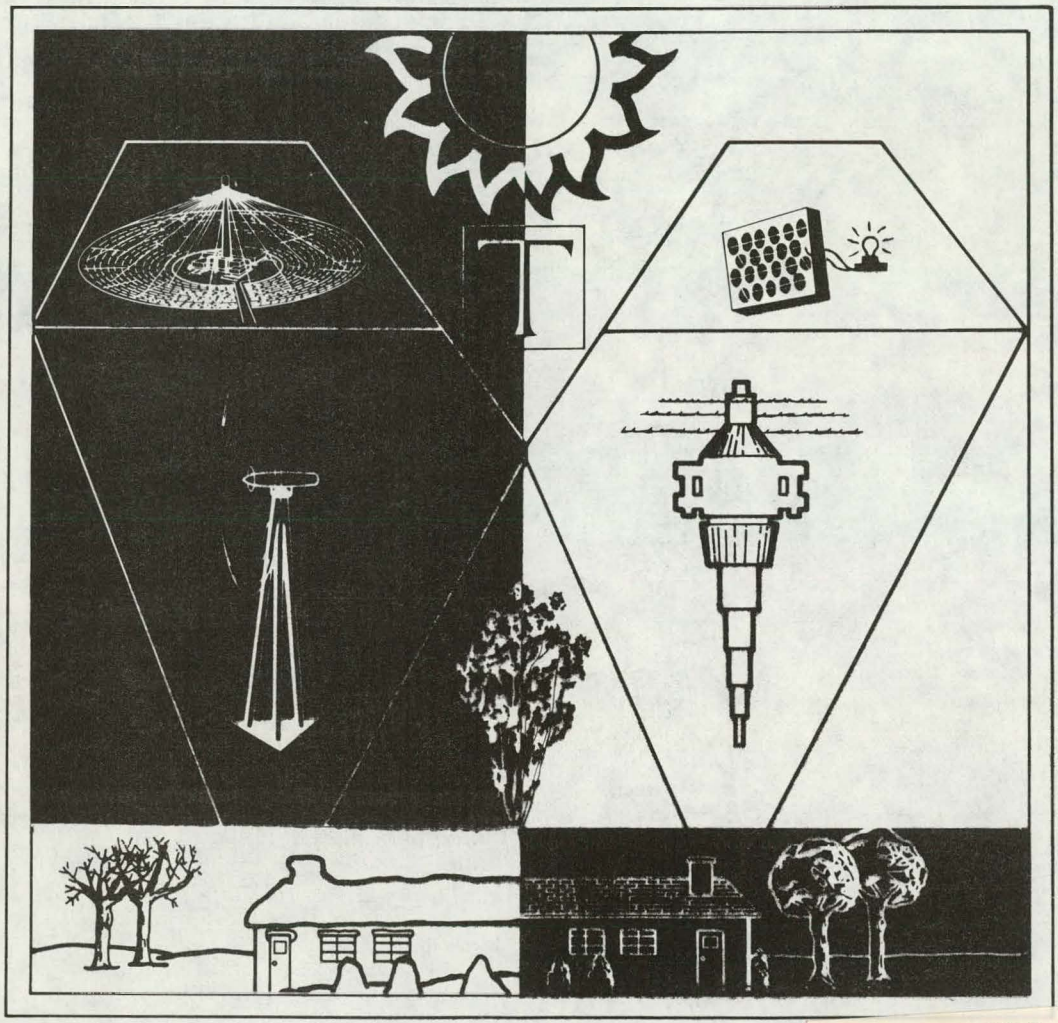

PROGRAM SUMMARY JANUARY 1978

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U.S. DEPARTMENT OF ENERGY

MOD–0A 200 kilowatt wind turbine and meteorological tower at Clayton, New Mexico field-test site.

Table of Contents

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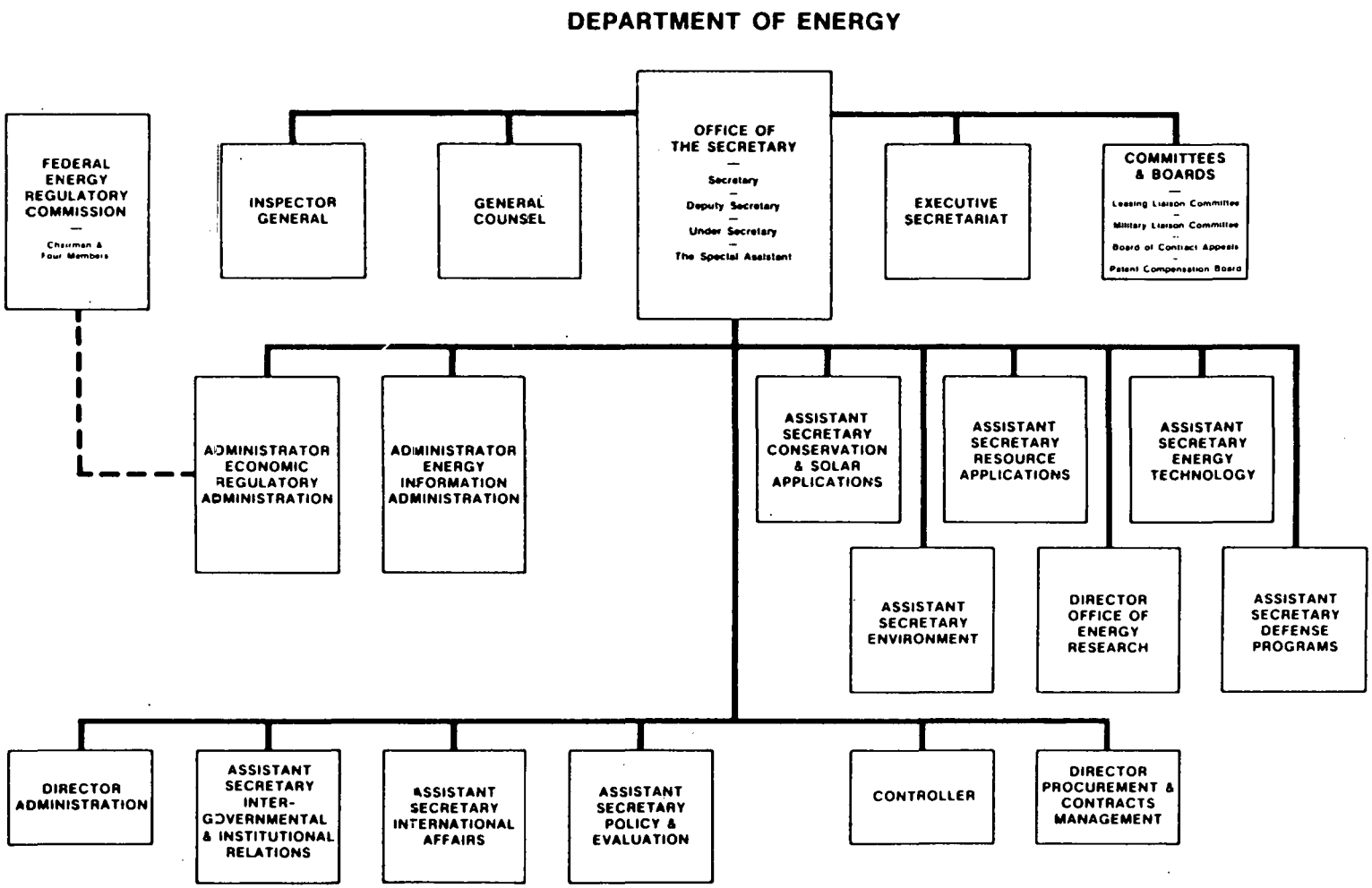


Figure 1. DOE Organization Overview

Introduction

The objective of the Federal Wind Energy Program is to accelerate the development of reliable and economically viable wind energy systems and enable the earliest possible commercialization of wind power. To achieve this objective for small and large wind systems requires advancing the technology, developing a sound industrial technology base, and addressing the non-technological issues which could deter the use of wind energy. This summary report outlines the projects being supported by the program through FY 1977 toward the achievement of these goals. It also outlines the program's general organization and specific program elements.

Wind energy conversion has long been recognized as a potentially abundant source of clean and renewable mechanical and electrical power. In 1973, the impending worldwide shortage of non-renewable energy sources and the Nation's increasing dependence upon imported fossil fuels led to a renewed effort to investigate the feasibility of converting the wind into useful energy.

At the start of the effort, it was recognized that a great many technical, economic, environmental, and social issues had to be resolved before significant benefits from wind power could be realized. It was also recognized that high cost was the greatest barrier to the use of wind systems. These costs had to be reduced to make wind power cost-competitive with other power sources. While much has been accomplished, the development of rugged, economical Wind Energy Conversion Systems (WECS) capable of providing up to 30 years of reliable, automatic, relatively maintenance-free service remains the program's primary challenge.

The Federal Wind Energy Program

The sizeable resources and the considerable economic risk-taking required to meet the challenge of wind power development led to the creation of a federal program to implement wide-ranging research and development (R&D) tasks and coordinate efforts in private industry, universities, and laboratories. The job was begun under the sponsorship of the National Science Foundation's Research Applied to National Needs (RANN) program in 1973, continued under the Energy Research and Development Administration (ERDA) during 1975 to 1977, and was transferred to the U.S. Department of Energy (DOE) in October 1977.

Program Elements

The Federal Wind Energy Program is designed to allow the earliest possible commercialization of wind power by simultaneously developing the WECS, assessing the technical, economic, and institutional requirements for their widespread use and stimulating their commercial utilization. At the same time, the program's iterative structure allows activities performed under discrete work elements to advance general and technical knowledge and the state-of-the-art in a systematic manner. The goal of this systematic research and development approach is to establish a firm base for wind systems by (1) performing research and development to build durable and economical wind systems, (2) performing field tests and testing applications to show that wind power can be implemented on both a small and large scale on a widespread basis, and (3) developing the technological capability of private industry to ensure that commercialization can be accomplished.

As shown in Figure 2, the program is organized into the following five discrete, yet interrelated program elements, each directed toward specific program objectives:

a. **Program Development and Technology (1.0)**
   (1) Mission Analysis (1.1)
   (2) Applications of Wind Energy (1.2)
   (3) Legal/Social/Environmental Issues (1.3)
   (4) Wind Characteristics (1.4)
   (5) Technology Development (1.5)
   (6) Advanced and Innovative Concepts (1.6)

b. **Farm and Rural (Small) Systems (2.0)**

c. **100 Kilowatt-scale Systems (3.0)**

d. **Megawatt-scale Systems (4.0)**

e. **Large Scale Multi-unit Systems (5.0)**

How The Program Works

Under the *Program Development and Technology* element (sub-elements 1.1 to 1.6) applied research and systems studies form the backbone of the Federal effort, defining national and regional wind power potential (1.1 and 1.2); assessing and ameliorating potential environmental, legal, and social barriers to wind power (1.3); developing economical methods of determining the wind resource on a national, regional, and site-specific basis (1.4); and developing components (1.5) and innovative wind systems (1.6) to lower system costs and advance the state-of-the-art. As wind system concepts are found to have potential for cost-effectiveness, several generations of *Farm and Rural Use (Small) Systems, 100 Kilowatt-scale Systems, or Megawatt-scale Systems* are being developed for testing in promising applications. Systems which show promise for large-scale power production will be developed further for use in *Large Scale Multi-unit Systems*. To lay the groundwork for the potential commercialization and mass production of wind systems, the program is designed to involve private industry at every stage in the development and fabrication of wind systems and to solicit the participation of potential users in applications studies, field-test projects, and other commercialization-oriented activities.

Current Program

The Federal wind systems R&D effort is continually modified to respond to planned change points in research emphasis. These changes are determined by the results and findings of projects within each program element and by redefinitions of the overall need for research, development, and demonstration (RD&D) to meet the national need. During FY 1977, increased emphasis has been placed upon small systems development and testing. Work has continued to accelerate on large systems with the initiation of field tests and the planned development of advanced horizontal-axis wind turbines. These program emphases and those highlighted in the section entitled "Program Highlights" will continue into FY 1978.

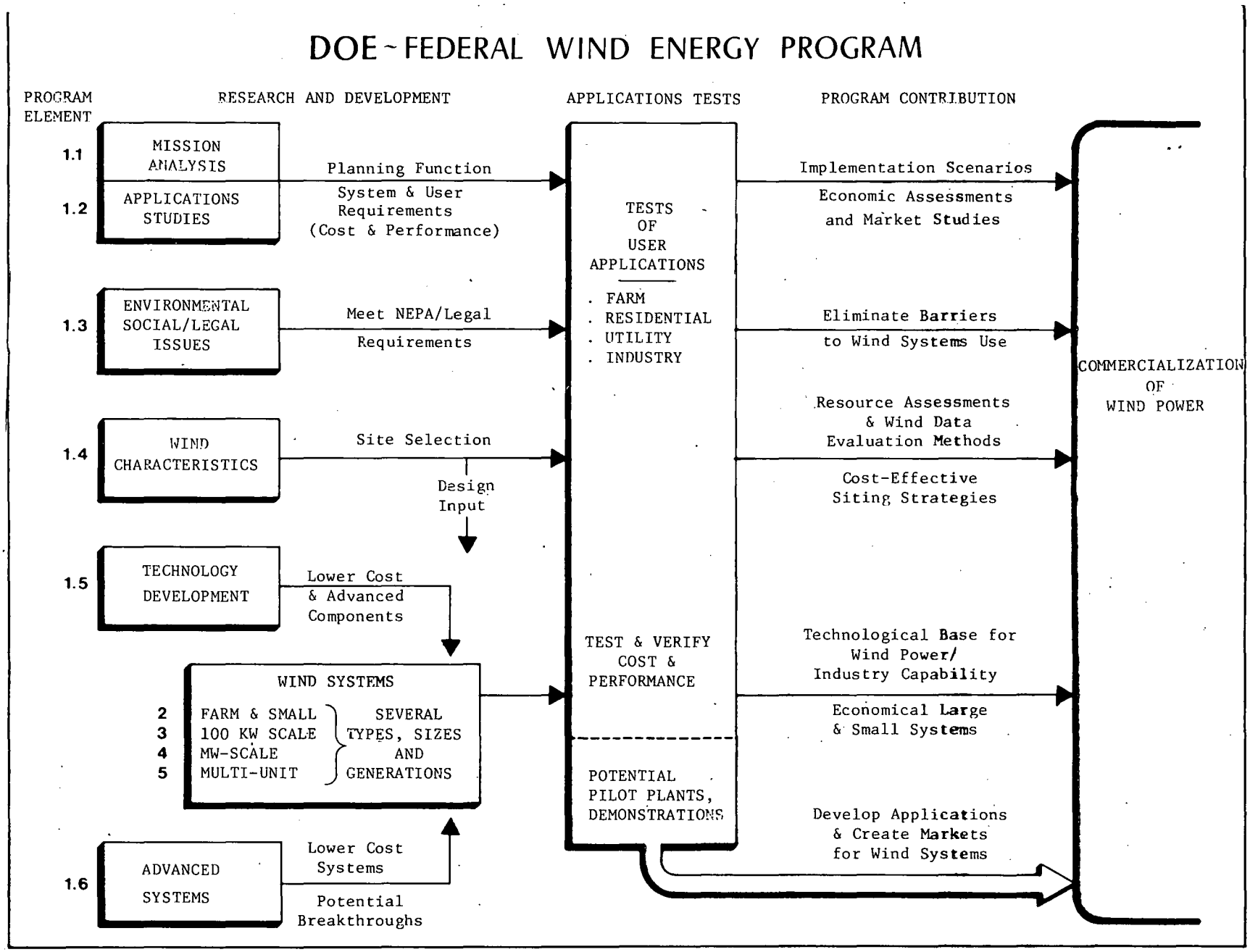

DOE - FEDERAL WIND ENERGY PROGRAM
PROGRAM ELEMENT
RESEARCH AND DEVELOPMENT
APPLICATIONS TESTS
PROGRAM CONTRIBUTION
1.1
MISSION ANALYSIS
1.2
APPLICATIONS STUDIES
Planning Function
System & User Requirements (Cost & Performance)
1.3
ENVIRONMENTAL SOCIAL/LEGAL ISSUES
Meet NEPA/Legal Requirements
1.4
WIND CHARACTERISTICS
Site Selection
Design Input
1.5
TECHNOLOGY DEVELOPMENT
Lower Cost & Advanced Components
WIND SYSTEMS
2
3
4
5
FARM & SMALL
100 KW SCALE
MW-SCALE
MULTI-UNIT
SEVERAL TYPES, SIZES AND GENERATIONS
1.6
ADVANCED SYSTEMS
Lower Cost Systems
Potential Breakthroughs
TESTS OF USER APPLICATIONS
. FARM
. RESIDENTIAL
. UTILITY
. INDUSTRY
TEST & VERIFY COST & PERFORMANCE
POTENTIAL PILOT PLANTS, DEMONSTRATIONS
Implementation Scenarios
Economic Assessments and Market Studies
Eliminate Barriers to Wind Systems Use
Resource Assessments & Wind Data Evaluation Methods
Cost-Effective Siting Strategies
Technological Base for Wind Power/ Industry Capability
Economical Large & Small Systems
Develop Applications & Create Markets for Wind Systems
COMMERCIALIZATION OF WIND POWER

Figure 2

Program Organization and Functional Responsibilities

While DOE's Wind Systems Branch maintains primary program management responsibility for the Federal R&D effort, many project management and management support duties have been assigned to DOE laboratories and cooperating Federal agencies, as shown in Figure 3. Some "in-house" research activities are carried out by these organizations, but their primary role is coordinating, directing, and monitoring R&D activities of industry, universities, and other organizations.

Program Highlights

• Program Development and Technology

Mission Analysis. A new study of remote and isolated area markets was begun during FY 1977. It now appears that these markets offer the potential for early wind power implementation to reduce dependence on high-priced, oil-based systems. A marketing study for the high-potential WECS applications identified in earlier mission analysis efforts will be initiated in mid-FY 1978. These studies will provide the first realistic estimates of the location and size of wind systems markets for use by WECS manufacturers and hardware distributors and will also provide potential marketing strategies. A study of potential economic incentives to wind systems commercialization will aid Federal planners by providing scenarios for wind systems implementation and estimating the cost and impact of various government incentives which could be used to stimulate commercialization.

Regional Applications Studies. With the completion of the first generation of studies of the potential of intertying wind systems with regional utilities in New England, Hawaii, Michigan, Minnesota, West Texas, and California, this program area will enter a new phase of increased specialization. Studies of the application of wind systems to Rural Electrification Administration (REA) cooperatives (including questions of privately owned WECS intertied with the grid), combined wind-hydroelectric, and local utilities will be initiated during FY 1978. Like the previous efforts, these studies will, in addition to providing information for a specific utility, provide generic information for all utilities of a general type or class. In particular, the studies will address the complex operational and economic questions associated with the use of wind power intermixed with existing conventional power systems.

Wind Characteristics Effort. Battelle-Pacific Northwest Laboratories (PNL) is responsible for the technical direction of the Wind Characteristics sub-element. Research projects in this field are concentrating on four areas: (1) the identification of wind characteristics relevant to wind turbine design and performance evaluation; (2) the investigation of mesoscale wind characteristics on regional and site-specific bases, including estimates of the size and reliability of the wind resource; (3) the development of siting methodologies documented in handbook form; and (4) the determination, on a power grid, of wind predictability and uncertainty characteristics needed by utilities concerned with WECS operations.

Ongoing Blade and Rotor Research Efforts. Work in this technology area is now emphasizing rotor development and investigations of the most economical rotor sizes and types, the structural dynamics of large rotors, and the prediction of rotor performance for use by designers. A 125-foot diameter composite (fiberglass) rotor is being compared with the metal rotor of the prototype MOD–0 wind turbine at the NASA-Lewis Research Center. A 150-foot blade will be static-tested in 1978 to determine the fabrication requirements and dynamics of fiberglass rotors in a size range which has never been attempted before.

Advanced Systems Research and Development. The Darrieus, vertical-axis (egg-beater-type) wind turbine being developed by Sandia Laboratories continues to be the most promising advanced system in terms of potential for early implementation and increased energy output per unit cost. The emphasis in FY 1977 has been on testing the 17-meter prototype. A low-cost version of this machine will soon be under development. Laboratory tests and investigations of a number of other innovative systems will continue.

• Farm and Rural Use Applications and Small Systems

Rocky Flats Small Systems Test and Development Center. During FY 1978, DOE's Rocky Flats facility in Golden, Colorado will continue to operate a center for the heavily instrumented and controlled testing of small wind systems. Rocky Flats is also coordinating the development of advanced, small WECS by private industry contractors. The primary goals of this long-term project are to determine the performance and capabilities of state-of-the-art systems, identify development needs, assist small machine manufacturers in the development and commercialization of advanced systems, and provide information and data to potential users of small WECS.

Development of Advanced 1 kW, 8 kW, and 40 kW WECS. Multiple contractors are being selected in late 1977 and 1978 to fabricate advanced small systems based on their competitively-selected designs. These machines, which include several innovative designs i

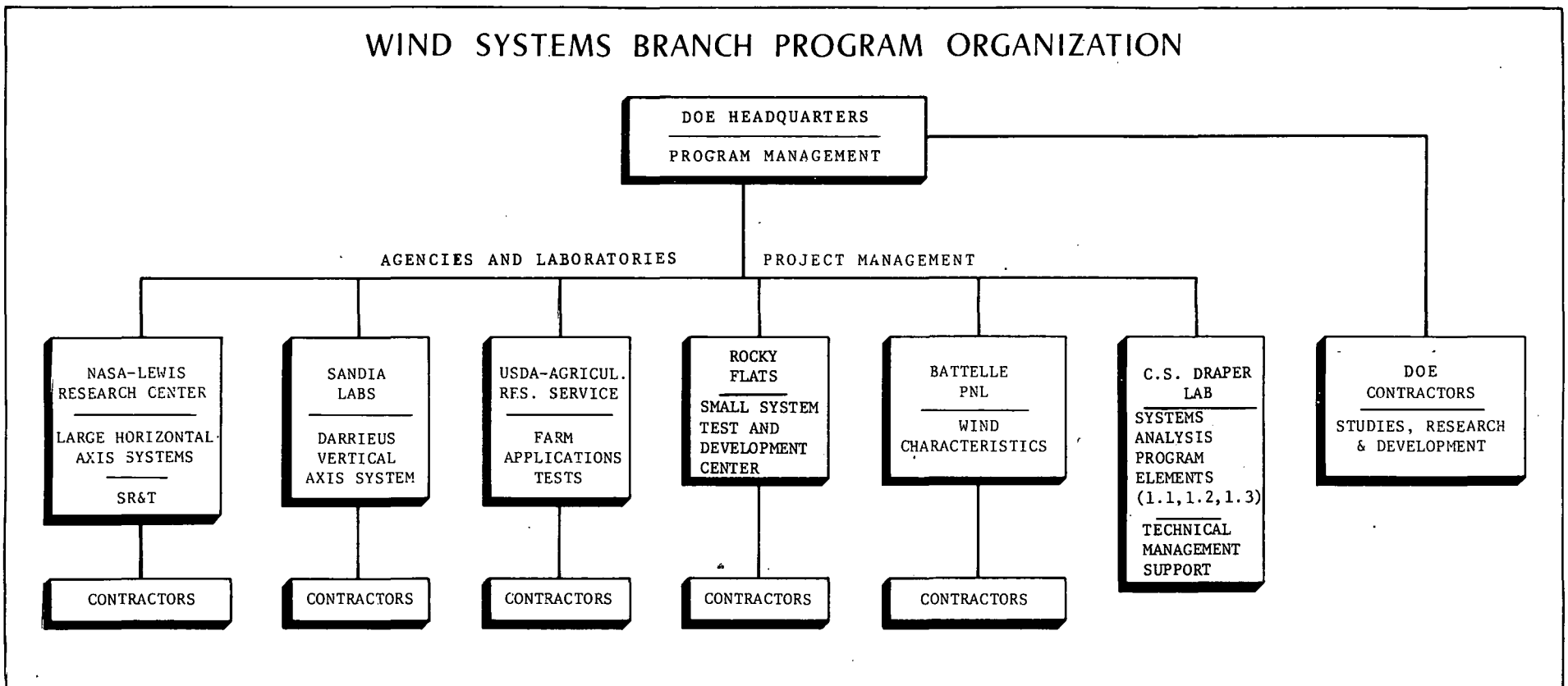

WIND SYSTEMS BRANCH PROGRAM ORGANIZATION
DOE HEADQUARTERS
PROGRAM MANAGEMENT
AGENCIES AND LABORATORIES
PROJECT MANAGEMENT
NASA-LEWIS RESEARCH CENTER
LARGE HORIZONTAL AXIS SYSTEMS
SR&T
SANDIA LABS
DARRIEUS VERTICAL AXIS SYSTEM
USDA-AGRICUL. RES. SERVICE
FARM APPLICATIONS TESTS
ROCKY FLATS
SMALL SYSTEM TEST AND DEVELOPMENT CENTER
BATTELLE PNL
WIND CHARACTERISTICS
C.S. DRAPER LAB
SYSTEMS ANALYSIS PROGRAM ELEMENTS (1.1,1.2,1.3)
TECHNICAL MANAGEMENT SUPPORT
DOE CONTRACTORS
STUDIES, RESEARCH & DEVELOPMENT
CONTRACTORS
CONTRACTORS
CONTRACTORS
CONTRACTORS
CONTRACTORS

Figure 3

addition to various propeller-type configurations, are expected to provide a mix of sizes which will satisfy an optimum number of small WECS applications. Each system will eventually be subjected to rigorous performance testing at Rocky Flats.

United States Department of Agriculture Test Program. USDA's Agriculture Research Service is responsible for managing projects to identify requirements for farm and agricultural wind systems use and to test and evaluate small machines in actual farm and rural applications. Disseminating information to the farm and agricultural community will be a major function of the program. Emphasis will be placed on applications which have "built-in" energy storage capabilities, such as residential hot water heating, or which are not tied to strict timing requirements, such as irrigation. Projects for the effort will normally be selected for funding through formal proposal solicitations (RFP's).

• 100 Kilowatt-scale Wind Systems

MOD–0 and MOD–0A. Testing of the prototype MOD–0 100 kW machine at NASA's Plum Brook Station has continued throughout 1977, with emphasis on collecting and analyzing test data and refining fully-automatic control techniques. In 1977, fully automatic, remote, and unattended operation was demonstrated. Automatic synchronous operation with the local utility grid was continually performed. During 1978, the MOD–0 will be used as a test bed for new and advanced components. Three MOD–0A machines, more powerful and slightly redesigned 200 kW versions of the MOD–0, will be installed and field-tested at utility sites during 1978 and 1979.

MOD–4 Development. The development of an advanced, low-cost 100 to 200 kilowatt wind turbine which could be used for irrigation, industrial, farm, and utility network applications has been initiated. The design phase for the system will include trade-off analyses of electrical, hydraulic, shaft, and other power outputs to determine the most cost-effective output which will satisfy the target applications. When fabricated, one or more machines will be tested at a competitively-selected user site.

• Megawatt-scale Systems

Preliminary conceptual studies of large wind systems, which examined alternate configurations and designs, have predicted that energy costs will decrease as these systems increase in size. This prediction will be verified by the development and testing of several large wind turbines.

MOD–1 Fabrication and Field Testing. General Electric is fabricating one MOD–1, 2 MW wind turbine under the direction of the NASA-Lewis Research Center. The system will have a rotor 208 feet in diameter. It is optimized for 18-mph average wind sites and will be field-tested at Howard's Knob, near Boone, North Carolina.

MOD–2 Development. The preliminary design of wind turbine with a 300-foot diameter rotor has bee initiated by Boeing Engineering and Construction. This MOD–2 wind turbine, with an expected output of from 2.5 to 3 MW, may be fabricated for field-testing at a competitively-selected utility site.

MOD–3 Development. Destined to be the first advanced design, second-generation megawatt-scale wind turbine, the MOD–3 design will be initiated in FY 1978 following a competitive procurement. Initially planned as a 200-foot diameter, horizontal-axis system, the MOD–3 will be designed for use in industrial and utility network applications.

Field-testing of 200 kW and 2 MW Wind Turbines. Seventeen candidate utility company sites for the field-testing of MOD–0A (200kW) and MOD–1 (2 MW) Wind Turbine Generators (WTG) were competitively selected in 1976. The first MOD–0A machine was installed at Clayton, New Mexico in late 1977. Two other kW units will be installed: one at Block Island, Rhode Island and one on the Island of Culebra, Puerto Rico. Boone, North Carolina was selected as a site for the 2–MW MOD–1 machine. Operation of these machines in a user environment is expected to provide valuable information about wind turbine design and the electrical control features of the wind system interface with utilities. Economic data and information about the institutional issues and requirements of utility-based wind systems will be important products of these experimental projects.

• Large Multi-unit Systems

Multi-unit systems were studied in two research projects carried out in 1977. One study, performed by General Electric, investigated the electrical stability requirements of wind turbines to provide machine designers and utility planners with information which will enable the use of large numbers of wind turbines in power systems. Another study, performed by Westinghouse, is examining the technical and economic feasibility of operating wind systems in various offshore environments and transmitting power (or hydrogen) to land-based users.

Program Funding

The funding history of the Federal Wind Program shows a steady increase in Federal involvement since 1973 (refer to Tables 1 and 2). Budget obligations for FY 1977 show a greater emphasis on wind machine developm

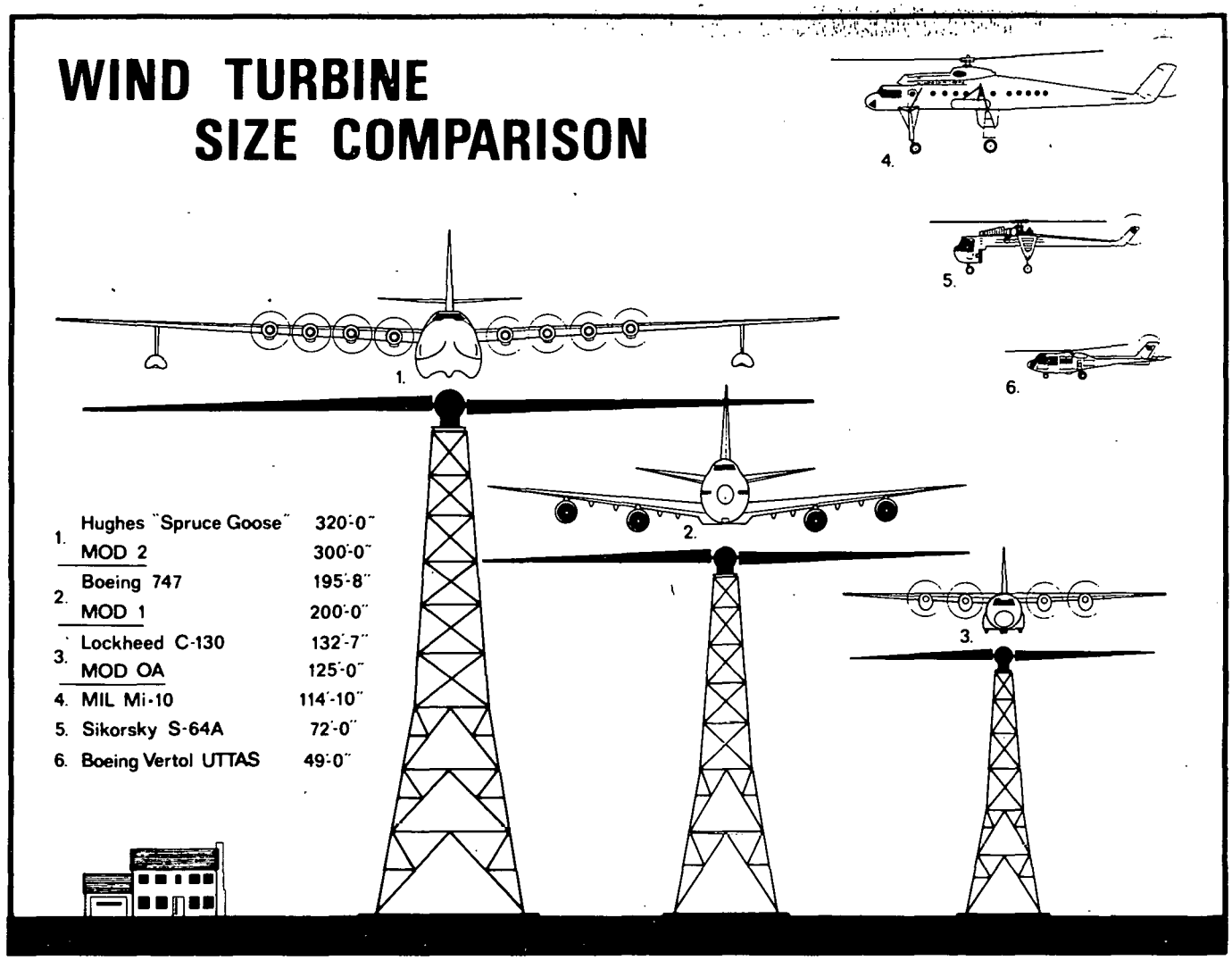
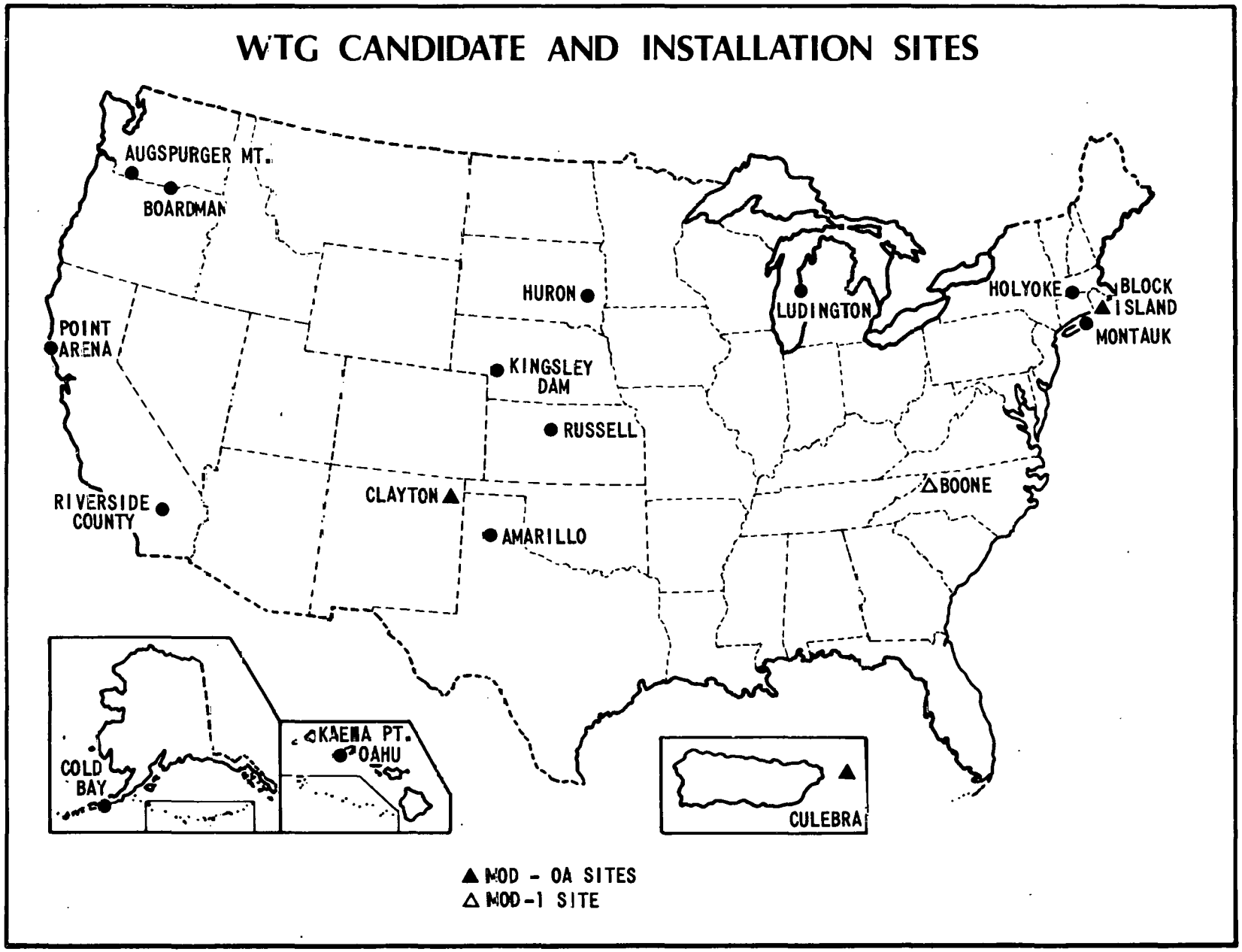


Figure 4. Wind Turbine Size Comparison


WTG CANDIDATE AND INSTALLATION SITES
AUGSPURGER MT.
BOARDMAN
POINT ARENA
RIVERSIDE COUNTY
HURON
KINGSLEY DAM
RUSSELL
CLAYTON
AMARILLO
LUDINGTON
HOLYOKE
BLOCK ISLAND
MONTAUK
BOONE
COLD BAY
KAENA PT.
OAHU
CULEBRA
▲ MOD - 0A SITES
△ MOD-1 SITE

PROGRAM ELEMENTS & WIND ENERGY FUNDING (x 1000)[a]

Program Elements/Sub-elements	FY 73-74[b]	FY 75[b]	FY 76	TQ[c]	FY 77	FY 78 (est.)
1. Program Development and Technology	429	5,605	7,698	2,987	7,925	9,303
1.1 Mission Analysis	12	1,043	831	371	1,272	
1.2 Applications of Wind Energy	--	579	556	230	160	
1.3 Legal/Social/Environmental Issues	--	422	200	300	199	
1.4 Wind Characteristics	14	399	992	669	1,900	
1.5 Technology Development	279	2,281	3,069	364	2,650	
1.6 Advanced Systems	124	881	2,050	1,053	1,744	
2. Farm and Rural Use (Small) Systems	--	736	1,507	231	2,661	8,000
3. 100 KW Scale Systems	865	970	1,439	628	1,464	2,900
4. MW Scale Systems	500	600	3,140	832	12,465	11,300
5. Large Multi-Unit Systems	--	--	582	292	25	2,150
TOTALS	1,794	7,911	14,366	4,970	24,500	33,653
Capital Equipment					1,100	1,400
Construction					2,000	--
TOTAL					27,600	35,053

a - In obligations; other federal documents may list outlays or costs incurred
b - includes NSF funding
c - Transition Quarter (July-September 1976)

Table 2.

Federal Wind Energy Program Primary Funding Distribution (Percent)

Program Elements	Other Federal Agencies	National Laboratories	Universities	Small Business Contractors	Other Contractors
Program Development and Technology	12	28	17	4	40
Farm and Rural Systems	14†	46°	9	23	7
100 kW-scale Systems	21	0	1	0*	78
Megawatt-scale Systems	4	0	0	0*	96

† Since USDA contracts utilizing FY 77 funding will actually be awarded in FY 78, distribution of this funding has been estimated.
° High percentage due to initial investment in Rocky Flats Small WECS Test and Development Center. Later FY's will show higher contractor percentages.
* Does not include small business subcontracts with private industry contractors.

The small systems effort was substantially augmented during FY 1977 and is expected to reach the $8 million level in FY 1978. Megawatt-scale systems development funding has also increased with the fabrication of the 200-foot MOD–1 wind turbine and the beginning of design work for the MOD–2 300-foot system.

The Future

Field tests of experimental wind systems in user environments begin a new phase in the Federal effort. As more detailed data is acquired and more experience gained in the fabrication and operation of propeller-type wind systems, the economic outlook for wind power will come into sharper focus. Development of these conventional systems will progress along two fronts: (1) the design of advanced systems to provide inexpensive, durable, small and moderate-sized systems for use in rural and remote areas and in applications such as irrigation, and (2) the fabrication and testing of experimental megawatt-scale systems for eventual commercialization and use by utility systems.

Current studies of innovative concepts will continue, with performance testing and cost analyses forming the basis for decisions on further development. At least one of these systems, the Darrieus, vertical-axis machine being developed by Sandia Laboratories, will reach this stage in 1978. Others will be developed and tested under the small advanced systems program managed by the Rocky Flats plant. Work on these concepts could culminate in the design and fabrication of large systems for testing at utility and other user sites if the performance per unit cost appears advantageous as compared to conventional propeller-type systems.

In the component and subsystems area, increased emphasis will be placed upon developing and testing low-cost, light-weight rotors and hubs and incorporating simplified design features to reduce manufacturing costs, increase service life, and decrease maintenance requirements.

The Wind Characteristics program will focus on the most promising of the current modeling methods for continued developments to enable cost-effective selection of single system and multi-unit sites. A comprehensive methodology will be developed for utilities and other users to enable selection of optimal wind energy sites under a full range of terrain and climate conditions for machines of various types and sizes. Close cooperation between Battelle PNL and designers will be an important aspect of the effort.

In the large systems area, the development of megawatt-scale machines, selection of additional test sites through future solicitations, and the completion of systems dynamics studies are expected to lead to the design of potential 10 to 100 megawatt multi-unit pilot plants. Possible testing of such plants in the early 1980's would lead to firm estimates of the economic feasibility of utility-based wind power and serve as an incentive to potential manufacturers and users.

Through the continued involvement of industry in the development of small and large systems and the participation of potential users in the design and operation of the pilot plants, it is expected that solid potential markets for the manufacture and use of economical wind machines will be created. It now appears that remote and isolated areas offer the potential for early wind power implementation to reduce the dependence of such areas on high-priced, oil-based energy systems. If the major issues can be resolved and the technical and economic feasibility of wind power can be firmly established, it is anticipated that private industry would assume the continued development and commercialization of wind systems, which is the overall goal of the program.

Current Wind Energy Projects

The summary tables and project summary sheets which follow include projects which were initiated or renewed by the Federal Wind Energy Program between December 1, 1976 and October 1, 1977. While all major research and development contracts are listed, some minor support efforts have been omitted. Funding refers to FY 1977 (obligations) unless otherwise noted. In some cases the funding does not reflect the total cost of multi-year contracts.

Since many contracts initiated prior to December 1, 1976 were not scheduled for renewal during the time period of this summary, the listing of projects does not provide a complete picture of the activity underway in each element. Thus, for a list and description of projects begun in previous years, the reader is referred to the Federal Wind Energy Program Summary Reports, dated October 1975 (ERDA–84, available from the National Technical Information Service [NTIS]) and January 1, 1977, (ERDA–77–32, available from the Government Printing Office [GPO] stock number 060–000–00048–4) These documents include descriptions of projects initiated prior to FY 1977 and, together with this report, comprise a total picture of the program's past and present activities.

Table 3

FY 1977 SUMMARY TABLES

Program Element

PROGRAM DEVELOPMENT AND TECHNOLOGY (1.0)

The objectives of this program element are to assess the national wind energy potential and develop strategies and technologies to realize this potential.

- *Program Sub-Element*

MISSION ANALYSIS (1.1)

The objectives of this sub-element are to refine estimates of national wind energy potential, identify and assess various applications and implementation scenarios, assess potential barriers to and benefits of wind systems, and investigate performance and cost characteristics required for acceptance of wind systems by various wind energy markets.

Organization	*Project*	*Contribution*
Energy Resources Company	A Market Analysis of the Potential for Wind Systems Use in Remote and Isolated Area Applications	Will provide private industry with a collection of facts to serve as a basis for determining the market potential for wind systems in isolated and remote areas and provide potential strategies for developing these markets.
Booz-Allen & Hamilton, Inc.	Assessment of Incentives to Wind Energy Conversion Systems	Will identify the most appropriate and effective forms of government incentives to WECS commercialization, identify their cost and effects, and describe how they could be implemented.
JBF Scientific Corporation	Wind Energy Systems Evaluation and Planning Studies	Will provide planning support information necessary for decisions on program activities, emphasis, schedule, and application of resources.
Charles Stark Draper Laboratory	Technical Management Support for Systems Analysis Elements of the Federal Wind Energy Program	Will ensure capability to manage DOE contractors under sub-elements 1.1, 1.2, and 1.3.

- *Program Sub-Element*

APPLICATIONS OF WIND ENERGY (1.2)

The objectives of this sub-element are to perform systems analyses of particular regional applications within the U.S. and determine user requirements, wind resource, cost and cost-sensitivity, and system performance and user interface requirements. Ongoing studies of utilities in New England and Hawaii were funded during FY 76.

Organization	*Project*	*Contribution*
Michigan State University	Application of Multi-unit Wind Systems to Electric Utilities	Will provide information for use by utilities in deciding on the feasibility for a particular region, handling the control and stability characteristics of WECS, and designing safe and economical wind systems.

- *Program Sub-Element*

LEGAL/SOCIAL/ENVIRONMENTAL ISSUES (1.3)

The objective of this sub-elements is to address the social and environmental impacts of the widespread use of wind systems.

Organization	*Project*	*Contribution*
University of Michigan	Broadcast Interference by Windmills	Will characterize the impact of wind turbines on the range of electromagnetic signals and provide guidance in siting to avoid these effects.
University of Illinois	Small Wind Turbine Owners Survey	Will define the attitudes of users and the problems and satisfactions of WECS ownership, and obtain suggestions for WECS manufacture and marketing through a survey of the owners of small WECS.

- *Program Sub-Element*

WIND CHARACTERISTICS (1.4)

The objectives of this sub-element are to improve the capability to economically locate and evaluate good wind sites for the various classes of wind systems and to provide design requirements for wind systems.

Organization	*Project*	*Contribution*
Battelle-Pacific Northwest Laboratory	Management Support for the Wind Characteristics Program Element	Will provide management support for the Wind Characteristics program element.
Colorado State University	Sites for Wind Power Installations	Will determine the influence of topography on wind speed and turbulence.
Georgia Institute of Technology	Energy Statistics for Large Wind Turbine Arrays	Will determine the effect of wind variability on power production of large-scale regional WECS arrays.
Oregon State University	Vegetation as an Indicator of Wind Velocities	Will determine the feasibility of using wind deformation of vegetation as an indicator of mean wind velocity.
University of Alaska	Alaskan Wind Power Study	Will determine the potential for wind power development in Alaska in terms of available wind data.
University of Virginia	Coastal Zone Wind Energy	Will determine the coastal zone wind energy potential from Maine to Texas and provide guidelines for determining favorable wind sites in coastal areas.
University of Wyoming	Locating Areas of High Wind Energy Potential through Remote Observations of Aeolian Features	Will determine the feasibility of identifying high wind sites from satellite imagery.
FWG Associates	Technology Development for Assessment of Small-scale Terrain Effects on Available Wind Energy	Will characterize the effect of micro-scale terrain features on near-surface winds.
Science Applications, Inc.	Development of a Wind Energy Site Selection Methodology	Will provide an improved methodology to extrapolate data to various sites throughout an area.
Lawrence Livermore Laboratory	Wind Power Studies	Will develop a general method of identifying potential WECS sites in an area.
Sandia Laboratories	Meteorological Studies for Wind Power	Will provide an assessment of the long-term reliability of wind power for various locations.

PROGRAM DEVELOPMENT AND TECHNOLOGY (1.0) (cont.)

WIND CHARACTERISTICS (1.4) (cont.)

Organization	*Project*	*Contribution*
Battelle-Pacific Northwest Laboratory		
Center for Environment and Man Geomet, Inc. Meteorology Research, Inc. Stanford Research Institute	Estimation of Wind Characteristics at Potential Wind Energy Conversion Sites	Will provide techniques for estimating wind characteristics at a site using available data at other locations.

- *Program Sub-Element*

TECHNOLOGY DEVELOPMENT (1.5)

The objective of this sub-element is to advance the performance and/or lower the cost of wind systems and mechanical and electrical subsystems.

Organization	*Project*	*Contribution*
AeroVironment, Inc.	Dynamic Inducer Test Program	Will determine the potential of tipvanes for improving rotor performance and estimate costs and cost benefits.
Oregon State University	Applied Acrodynamics of Wind Turbines—Aeromechanical	Will provide a designer's handbook documenting simplified techniques for estimating the aeromechanical characteristics of wind turbine designs.
NASA-Lewis Research Center	Supporting Research and Technology Program	Will develop technology required to reduce wind system costs, improve their performance and reliability, and increase their service life.
Subcontractors:		
Kaman Aerospace Corp.	150-foot Wind Turbine Blade Project	
Gougeon Brothers	Wood Blade Study	
Tuthill Pump Co.	Prestressed Concrete Blade Study	
DEFU (The Research Association of the Danish Electricity Supply Undertakings)	A Preliminary Test Program for the Gedser Wind Turbine	Provide data from an earlier large wind turbine for comparison with current and planned DOE designs.

- *Program Sub-Element*

ADVANCED SYSTEMS AND INNOVATIVE SYSTEMS (1.6)

The objective of this sub-element is to determine the technical and economic feasibility of alternative or innovative concepts and wind system configurations.

Organization	*Project*	*Contribution*
Polytechnic Institution of New York	Wind Augmentors for Wind Energy Conversion	Will demonstrate and determine the potential of the delta wing vortex device for improved performance per unit cost over conventional systems.
West Virginia University	Innovative Wind Turbines	To determine the cost and performance benefits of a vertical axis device which features circulation control of the airflow across its articulated rotor.

PROGRAM DEVELOPMENT AND TECHNOLOGY (1.0) (cont.)

Organization	*Project*	*Contribution*
arks Polarized Corporation	Tests and Devices for Wind/Electric Power Charged Aerosol Generator	Will characterize five methods of producing charged particles for electrofluid dynamic wind power generators.
University of Dayton	Electrofluid Dynamic (EFD) Wind Generator	Will develop a practical configuration for the EFD wind generator and determine its performance and economics.
Grumman Aerospace Corporation	Diffuser Augmented Wind Turbine	Will refine a diffuser design developed under previous efforts and provide data to allow assessment of the design's potential cost benefits.

Program Element

FARM AND RURAL USE (SMALL) SYSTEMS (2.0)

The objectives of this program element are to identify and test applications of small wind systems, assess the performance of available small wind turbines for these applications, identify small machine development needs, and develop and evaluate advanced small wind turbines.

Organization	*Project*	*Contribution*
USDA-Agricultural Research Service	Development of Rural and Remote Applications of Wind Generated Energy	Will provide test information and guidance to potential users of wind systems in rural and remote applications.
ARS-Manhatten, Kansas	Low Lift Pumping	Will provide data and operational characteristics of a wind-powered, low-lift irrigation pump.
Virginia Polytechnic Institute	Apple Storage Cooling	Will provide information on the practicality of using wind power for apple storage cooling.
Cornell University	Direct Hydraulic Dissipation to Heat	Will provide data on the possibility of converting wind power to heat through hydraulic dissipation.
Kaman Sciences Corporation	Dairy Milk Cooling	Will provide operation data on the performance of a wind turbine-powered refrigeration system for milk cooling.
ARS-Beltsville, Maryland	Dairy Milk Cooling/Water Heating	Will provide operation data for a hybrid system, utilizing a heat pump, for milk cooling and the preheating of sanitation wash water.
DOE Rocky Flats Plant	Technical and Management Support for the Development of Wind Systems for Farm, Remote and Rural Use	Will develop and test small wind systems to increase performance and reliability and reduce their costs.
University of Massachusetts	Investigation of the Feasibility of Using Wind Power for Space Heating in Colder Climates	Will provide an initial verification of the cost and practicality of heating homes by wind power.
North Wind Power Co. Enertech :rospace Systems, Inc.	Development of a 1 kW High Reliability Wind Turbine Generator	Will provide three advanced designs, together with manufacturing and performance data sufficient to verify cost and reliability.

FARM AND RURAL USE (SMALL) SYSTEMS (2.0) (cont.)

Organization	*Project*	*Contribution*
DOE Rocky Flats Plant		
Windworks United Technologies Research Center Alcoa Grumman Corporation	8 kW Wind Turbine Generator Development	Will develop and test four 8 kW wind turbine designs and determine their costs and durability.
Contractors TBD	Development of a 40 kW Wind Turbine Generator	Will provide two advanced 40 kW designs, together with performance data to verify their cost and durability.

Program Element

100 KILOWATT-SCALE SYSTEMS (3.0)

The objectives of this program element are to develop moderately-sized wind systems for applications such as irrigation and small-scale industry and utility use and to support the development of larger systems.

Organization	*Project*	*Contribution*
NASA-Lewis Research Center Subcontractors: Westinghouse Electric Company—machine Lockheed—blades Cooperating Utilities: Town of Clayton, Clayton, N.M. Block Island Power Company, Block Island, Rhode Island Puerto Rico Water Resources Authority, Island of Culebra, Puerto Rico	Experimental Wind Energy Systems for Early User Applications (MOD–0A WTG)	Will provide manufacturing and field-test data to determine machine operating performance and dynamic characteristics and the economics of large utility-based wind systems.

MEGAWATT-SCALE SYSTEMS (4.0)

The objective of this program element is to develop durable and economical large systems for eventual use by large power producers, such as the Nation's public and private electric utility systems.

Organization	*Project*	*Contribution*
NASA-Lewis Research Center Subcontractor: General Electric—Space Division Cooperating Utility: Blue Ridge Electrical Membership Corporation, Boone, N.C.	MOD–1 2-Megawatt Wind Turbine 300-foot Diameter Wind Turbine	Will determine manufacturing requirements and operational characteristics, and provide information on the feasibility of a utility-generated megawatt-scale wind turbine.
NASA-Lewis Research Center Subcontractor: Boeing Engineering and Construction	MOD–2 Project	Will provide information on the practicality of using 300-foot diameter rotors to increase cost-effectiveness at moderate wind sites and identify and solve problems associated with constructing turbines of this size.

LARGE SCALE MULTI-UNIT SYSTEMS (5.0)

The objectives of this program element are to study the technical and economic requirements of operating large arrays of megawatt-scale wind systems and demonstrate how WECS could supply a considerable percentage of an electric utility system's generating capacity.

(Studies of multi-unit WECS stability and off shore systems funded during FY 76 are now being completed. Additional studies will be funded during FY 78.)

Fiscal Year 1977—Project Summary Sheets

TITLE	ORGANIZATION
Technical Management Support for Systems Analysis Elements of the Federal Wind Energy Program	Charles Stark Draper Laboratory 555 Technology Square Cambridge, MA 02139
AMOUNT	PRINCIPAL INVESTIGATOR
$250,000	Arthur Parthé

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Cambridge, MA	12 months—Sept. 30, 1977	EG-77-C-01-4125

PROJECT SUMMARY:

Objective:

The objective of this project is to ensure the necessary systems capability to manage DOE contractors engaged in systems analysis studies, including (1) mission analysis; (2) applications of wind energy; and (3) legal, social and environmental issues.

Approach:

Draper Laboratory is planning, providing work specifications for, coordinating, and monitoring the activities of DOE contractors working on mission analysis, regional applications, and legal, social, and environmental studies. Draper is to ensure the quality of information produced by these contractors; prepare reports and reviews relevant to specific technical issues and economic questions; and ensure that work in interrelated study areas is motivated by a systems approach to technical and nontechnical requirements, problems and issues.

Output

The project is to provide technical reviews and reports pertinent to the systems analysis program elements. In addition, the project is to develop planning documents, work plans, and statements.

TITLE	ORGANIZATION
A Market Analysis of the Potential for Wind Systems Use in Remote and Isolated Area Applications	Energy Resources Company, Inc. 185 Alewife Brook Parkway Cambridge, MA 02138
AMOUNT	PRINCIPAL INVESTIGATOR
$ 94,633	John Edwards

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Cambridge, MA	12 months—Sept. 30, 1977	EG-77-C-01-4051

PROJECT SUMMARY:

Objective

The project objective is to define, study, and estimate the size of markets for small and large wind systems in remote and isolated areas of the U.S. and Canada, their continguous islands, and the West Indies. In addition, this project is to provide private industry with a collection of facts to serve as a basis for determining the market potential for commercial wind systems in these areas and provide strategies for developing these markets.

Approach

Categories for wind system applications for isolated and remote area applications are being developed. Applications are to be further categorized according to average wind speed requirements. The base current market potential for each regional category is then to be estimated and adjusted by considering external controlling factors (i.e., fuel costs and energy demand, etc.) and user characteristics and requirements. For each regional category, a potential marketing strategy for use in possible marketing efforts by private industry is to be developed.

Output

The study is to provide a collection of facts on which wind system manufacturers and suppliers can base projections for sales. In addition, potential marketing strategies are to be provided.

TITLE	ORGANIZATION
Assessment of Incentives to Wind Energy Conversion Systems	Booz-Allen & Hamilton, Inc. 4773 Bethesda, Avenue Bethesda, MD 20014
AMOUNT	PRINCIPAL INVESTIGATOR
$ 120,665	Michael Lotker

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Bethesda, MD	8 months—Sept. 30, 1977	EG-77-C-01-4053

PROJECT SUMMARY:

Objective

The objective of the project is to identify the most effective forms of government economic incentives to commercialize large and small wind systems in various applications. Additionally, the project is to identify the cost and effects of the incentives and describe how the incentives could be implemented and timed.

Approach

WECS technology implementation scenarios are being defined and diagrammed. After an assessment of barriers to WECS implementation, government incentives, which can mitigate these barriers, are to be identified and analyzed. The costs, effects, benefits, and problems associated with these incentives are also to be defined. In addition, criteria for selecting appropriate incentives are to be developed.

Output

The study being performed will provide an assessment of incentive scenarios and alternatives. This assessment will enable DOE to decide the optimum use, cost, and effect of various types of incentives.

TITLE	ORGANIZATION
Wind Energy Systems Evaluation and Planning Studies	JBF Scientific Corporation 1925 N. Lynn Street Suite 308 Arlington, VA 22209
AMOUNT	PRINCIPAL INVESTIGATOR
$ 350,000	Ted Kornreich

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Arlington, VA	12 months—Sept. 23, 1977	E(49-18)-2521

PROJECT SUMMARY:

Objective

These studies are being performed to provide the planning support information necessary for management decisions on program activities, emphasis, schedule and application of resources.

Approach

Specific task and priorities are being assigned in three task areas, including (1) an overview of WECS state-of-the-art to integrate and compare related information from different sources within and outside the Federal program and determine the reasons for variances in this information; (2) the development and assessment of alternative program approaches; and (3) the development of systems to assure that pertinent wind systems information developed inside and outside the Federal program is easily accessible for use by technical specialists and the general public.

Output

A major contribution of these studies is to produce a series of comprehensive reports and planning documents. These are to be provided on a rapid response basis to satisfy specific program management needs and schedules.

TITLE	ORGANIZATION
Application of Multi-unit Wind Systems to Electric Utilities	Michigan State University (MSU) College of Engineering Department of Electrical Engineering and Systems Science East Lansing, MI 48824
AMOUNT	PRINCIPAL INVESTIGATOR
$ 141,000	Gerald Park

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
East Lansing, MI	15 months—July 1, 1977	EG-77-S-02-4450

PROJECT SUMMARY:

Objective

This effort is continuing work performed under previous contracts by providing information for use by electric utilities. This task includes determining the feasibility of wind power for a particular regional system; developing strategies to implement wind power and handle the control and stability characteristics of Wind Turbine Generators (WTG); and designing safe and economical power systems incorporating these generators.

Approach

MSU uses a representative utility as a model to determine the effect of WTG power fluctuations on the power flows, frequencies, and other characteristics of the utility's electrical system. The characteristics and problems associated with WTG power penetration of 10 to 30 percent of normal peak load are being identified, assessed, and reviewed with the utility. Results of previous MSU work are being documented in a WECS application manual for use by medium to small electric utilities in determining the feasibility of intertying WECS with their systems. In addition, the progress and results of DOE multi-unit wind systems studies are being monitored.

Output

The project is to provide information and data sufficient to enable utility engineers to identify and plan for changes in operating control programs required by WECS. A WECS application manual will be produced using examples to describe and illustrate the steps required to determine WECS feasibility.

TITLE	ORGANIZATION
Broadcast Interference by Windmills	University of Michigan Radiation Laboratory Department of Electrical and Computer Engineering Ann Arbor, MI 48109
AMOUNT	PRINCIPAL INVESTIGATOR
$ 100,000	Thomas B.A. Senior

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Ann Arbor, MI	12 months—Jan. 1, 1977	EY-77-S-02-2846

PROJECT SUMMARY:

Objective

The objectives of this effort are to (1) quantify the wind turbine-induced radio frequency interference identified during the first year of the project; (2) develop simple techniques for assessing the impact of this interference; and (3) investigate the effect on other aspects of the electromagnetic environment.

Approach

The model for determining wind turbine-induced TV interference is being further developed to provide simpler expressions and greater accuracy. Extended laboratory simulations and field tests of this interference are performed as an input to the model. In addition, the effect on AM and CB radio, microwave links, VOR transmissions, and navigation radar are analyzed and siting criteria to avoid these effects are being developed. The signal scattering characteristics of existing and planned fiberglass blades are being measured or estimated. Finally, the scattering reduction that would be achieved using other feasible non-metallic materials and structures are being theoretically examined.

Output

The project is providing a model for the simplified calculation of wind turbine effects on TV broadcasts and a handbook to enable the hand calculation of interterence zones near a wind turbine. The effects on other electromagnetic signals are being characterized, and simple procedures are being provided to enable the avoidance of these effects at any locale, given a minimum of information and data. The scattering of signals by fiberglass and other non-metallic blade materials are being characterized as an input to these models and procedures.

1.3 LEGAL/SOCIAL/ENVIRONMENTAL ISSUES

TITLE	ORGANIZATION
Small Wind Turbine Owners Survey	University of Illinois Survey Research Center Urbana, IL 61801
AMOUNT	PRINCIPAL INVESTIGATOR
$ 68,200	Robert Ferber

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Urbana, IL	12 months—Sept. 1, 1977	EG–77–S–02–4549

PROJECT SUMMARY:

Objective

This survey is to help determine the extent of current wind energy use, identify demographic and attitudinal variables relative to its use, identify the problems and satisfactions of wind system ownership, and compile owner suggestions for improvements in wind machine manufacture and marketing.

Approach

An extensive search for owners of small wind machines is being made by contacting manufacturers, wind energy organizations, utilities, and the owners themselves. A statistical probability sample is being selected, contacted, and asked a variety of pertinent questions in phone interviews. Also, a small follow-up sample is being selected for personal interviews. Data are then to be edited, reduced, processed, and analyzed.

Output

A final report is to contain the resulting data, fully processed to provide usable information. Straight frequencies for all variables and cross-tabulations of related variables are also to be obtained. Further statistical analyses are to be made where useful information will result.

TITLE	ORGANIZATION
Management Support for the Wind Characteristics Program Element	Battelle Memorial Institute Pacific Northwest Laboratory Battelle Boulevard Richland, WA 99352
AMOUNT	PRINCIPAL INVESTIGATOR
$ 1,900,000	C.E. Elderkin

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Richland, WA	12 months—Oct. 1, 1977	EY–76–C–06–1830

PROJECT SUMMARY:

Background

Battelle, Pacific Northwest Laboratory (PNL) has provided technical and management support for the Wind Characteristics Program Element (WCPE) since April 1976. During FY 1977, there were 21 active contracts in various stages of completion. Seventeen of these contracts were funded from the PNL budget.

Objective

The primary objective of the WCPE is the development and dissemination of information on wind characteristics relating to the siting design and utilization of wind systems.

Approach

To accomplish the objective of the WCPE in FY 78, the overall effort at PNL has been divided into five technical areas:

(1) Wind Characteristics for Design and Performance Evaluation.
(2) Mesoscale Wind Characteristics.
(3) Siting Methodologies.
(4) Wind Characteristics for WECS Operations.
(5) Special Studies.

The program is designed to place the majority of the funding with industry and universities, and a significant portion of the PNL effort is in the area of coordinating and contract monitoring. Close coordination is maintained with the Wind Systems Branch.

Output

Information developed by the program will aid mission analysis planners, WECS designers, organizations, and individuals interested in WECS siting and operations. Documents are to be designed for ready assimilation into the ongoing efforts of other segments in the program as well as the wind energy community at large.

TITLE	ORGANIZATION
Sites for Wind Power Installations	Battelle—PNL Subcontract: Colorado State University Department of Civil Engineering Fort Collins, CO 80523
AMOUNT	PRINCIPAL INVESTIGATOR
$ 85,357	R.N. Meroney and V.A. Sanborn

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Fort Collins, CO	12 months—June 1, 1977	EY–76–S–06–2438

PROJECT SUMMARY:

Objective

The objective of this project is to apply wind tunnel techniques in determining the influence of topography on wind speed and turbulence as they affect the placement and performance of WECS in complex terrain.

Approach

A laboratory wind tunnel has been used to study airflow over various types of hills. The analysis of data collected from measurements of wind speed, static pressure, and turbulence intensity has been analyzed and organized into graphical and tabular form. These analyses are designed to provide information on the influences of topographic profile, surface roughness, insolation, and stratification. The study is continuing the analysis by applying this approach to increasingly complex terrain configurations. Existing field data will be used for the wind tunnel results.

Output

Three reports and papers have been produced discussing the influences of two-dimensional ridges on wind speed and turbulence. Similar reports on the results of tests with the new three-dimensional shapes are to be provided.

TITLE	ORGANIZATION
Energy Statistics for Large Wind Turbine Arrays	Battelle—PNL Subcontractor: Georgia Institute of Technology School of Aerospace Engineering Atlanta, GA 30332
AMOUNT	PRINCIPAL INVESTIGATOR
$ 84,000	C.J. Justus

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Atlanta, GA	12 months—May 1, 1977	EY–76–S–06–2439

PROJECT SUMMARY:

Objective

The major objective of this continuation of previous work is to examine the effect of wind variability on the power production from simulated large-scale arrays of wind turbines in various geographic regions of the United States. Another objective is to develop and verify a simplified array simulation model which does not require time series analysis.

Approach

Wind data from selected National Weather Service stations are used to compute time and spatial correlations of wind speed, wind power distributions, and the distribution of return times. Analyses have been completed for the Central Plains and the New England-Middle Atlantic areas. During FY 1977, the Great Lakes and Pacific Coast areas were analyzed. The results were used to verify a simplified array simulation model. Analysis will continue with emphasis on large multi-region arrays and the long-term reliability of wind power.

Output

A report on the Great Lakes and Pacific Coast analyses has been published. The simplified array simulation model was shown to represent the observed results reasonably well. Both the model and observed results indicated a significant improvement in wind power reliability when the sites were dispersed over a relatively large area.

TITLE	ORGANIZATION
Vegetation as an Indicator of Wind Velocities	Battelle—PNL Subcontractor: Oregon State University Department of Atmospheric Sciences Corvallis, OR 97331
AMOUNT	PRINCIPAL INVESTIGATOR
$ 49,880	E. Wendell Hewson

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Columbia Gorge and Oregon Coast	8 months—June 15, 1977	E(45-1)-2227

PROJECT SUMMARY:

Background

This program was initiated to examine the feasibility of using the growth and appearance of vegetation as an aid to locating favorable wind energy areas.

Objective

The objective of this work is to calibrate in terms of mean wind velocity the type and degree to which vegetation has been deformed by the wind.

Approach

During the first year of this study the work was divided between two geographic areas: the Columbia Gorge and the Oregon coast. Work in the Columbia Gorge region consists of calibrating crowns of conifers at three study sites. Cameras are installed to record the change in the appearance of the trees which can be correlated with wind records. At the Oregon coast, an experimental site has been established for the comparison of the growth of vegetation between obstructed and unobstructed wind regimes. Some work has been carried out to develop techniques to analyze tree rings which could determine wind history.

Output

Published reports of the calibration results should prove valuable in providing an initial screening tool to those who are doing preliminary site survey work in two or more areas with similar vegetation.

1.4 WIND CHARACTERISTICS

TITLE	ORGANIZATION
Alaskan Wind Power Study	Battelle—PNL Subcontractor: University of Alaska Geophysical Institute Fairbanks, AK 99701
AMOUNT	PRINCIPAL INVESTIGATOR
$ 75,874	Tunis Wentink, Jr.

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Various Locations in Alaska	12 months—Sept. 1, 1977	E(45-1)-2229 #12

PROJECT SUMMARY:

Background

This project was initiated in May 1976 and was transferred to the Wind Characteristics program element in February 1977. Earlier studies (prior to 1976) on Alaskan wind power have included: wind analyses for selected locations, field measurements and operation of a 6 kW windmill, applications of wind energy in Alaska, and economic studies.

Objective

The primary objective of this work is to determine the potential for the development of wind power throughout Alaska, using currently available data.

Approach

Wind data from 28 Alaskan sites were analyzed, and the velocity duration curves were evaluated. The vertical shear of wind speed was analyzed from data collected at a coastal and inland site. Analyses of wind data from additional stations throughout Alaska are continuing to provide the basis for an estimate of the wind power potential throughout Alaska. Variations in anemometer height and exposure are being evaluated and these will be accounted for, where possible, in the wind power estimates.

Output

A report on the evaluation of the wind data at the 28 stations has been submitted. A final report is to be issued which will provide a summary of wind characteristics in Alaska for currently available data.

TITLE	ORGANIZATION
Coastal Zone Wind Energy	Battelle—PNL Subcontractor: University of Virginia Department of Environmental Sciences Charlottesville, VA 22903
AMOUNT	PRINCIPAL INVESTIGATOR
$ 76,642	M. Garstang
WORK LOCATION	DURATION-AWARD DATE
Charlottesville, VA	12 months—Sept. 15, 1977
CONTRACT NO.	
EY-76-S-06-2344	

PROJECT SUMMARY:

Background

The wind in the vicinity of a coastline is affected by a complex interaction of land/sea temperature differences, the large-scale velocity field and surface roughness. This work began in September 1976 to study this interaction through the application of a two-dimensional version of a sea breeze circulation model.

Objective

The objectives of this effort are to appraise the coastal zone wind energy potential from Maine to Texas, to apply a model for determining the most favorable wind power locations relative to a coastline, and to examine wind characteristics for storm and non-storm conditions.

Approach

The initial step in this work was to subdivide, on a climatological basis, the coastline from New England to Mexico into five coastal regions for separate analysis. Both high frequency and standard meteorological data from four sources have been acquired and compiled for use in determining the coastal wind characteristics and verification of modeling efforts. The two-dimensional model has been tested and applied under various meteorological conditions.

Output

The output of the project is to include the results of the data analyses (based on all currently available coastal and offshore data) and the model calculations.

1.4 WIND CHARACTERISTICS

TITLE	ORGANIZATION
Locating Areas of High Wind Energy Potential Through Remote Observations of Aeolian Features	Battelle—PNL Subcontractor: University of Wyoming Department of Geology Laramie, WY 82071
AMOUNT	PRINCIPAL INVESTIGATOR
$ 49,815	R.W. Marrs

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Laramie, WY	6 months—April 1, 1977	EY–76–S–06–2343

PROJECT SUMMARY:

Objective

The main objective of this project is to develop an efficient and effective method of identifying potentially high wind areas over a vast region. This is accomplished by inferring wind characteristics from wind-modified geologic features observed in LANDSAT satellite imagery.

Approach

Work in this project was initially divided into three main tasks: (1) determining the utility of stabilized aeolian features as indicators of present-day wind characteristics; (2) developing techniques for quantitatively estimating wind characteristics from aeolian features; and (3) determining the applicability of LANDSAT imagery for locating areas of high wind energy potential in several regions of the country. Continued efforts in this project are to concentrate on tasks 2 and 3.

Output

Reports of the results of the three tasks have been published indicating some success in tasks 2 and 3. Analysis of LANDSAT imagery in eastern Washington using the technique developed from the Wyoming analyses were found to delineate areas of high wind which were in fair agreement with surface data where it was available. Reports of the more concentrated efforts as well as a documentation of the methods developed are to be published.

TITLE	ORGANIZATION
Technology Development for Assessment of Small Scale Terrain Effects on Available Wind Energy	Battelle—PNL Subcontractor: FWG Associates, Inc. R.R. 3 Box 201–B Tullahoma, TN 37388
AMOUNT	PRINCIPAL INVESTIGATOR
$ 161,315	Walter Frost

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Tullahoma, TN	12 months—Sept. 1977	EY–76–C–06–2443

PROJECT SUMMARY:

Background

Rcliable information regarding the effect of small-scale terrain features on the wind near the surface is needed to evaluate the suitability of specific sites for WECS installations.

Objective

The project objective is to characterize and catalog the effect of microscale terrain features on the near-surface wind.

Approach

Existing knowledge in the disciplines of fluid mechanics and meteorology of flow over flat surfaces as well as flow over two- and three-dimensional obstacles is being surveyed from the standpoint of its usefulness to WECS siting. This information is then to be compiled in terms of guidelines and rules-of-thumb that would enable a user to determine the probable effect of local terrain on the wind. An experimental field program is being designed to verify the accuracy of these guidelines. The instrumentation required for these experiments is also being identified.

Output

A handbook is to be produced which provides methods for an engineer to use in selecting an optimum site (from the standpoint of wind power) for a WECS within a small area.

TITLE	ORGANIZATION
Development of a Wind Energy Site Selection Methodology	Battelle—PNL Subcontractor: Science Applications, Inc. 1200 Prospect Street LaJolla, CA 92038
AMOUNT	PRINCIPAL INVESTIGATOR
$ 40,000	R.M. Traci

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
LaJolla, CA	12 months—Sept. 23, 1977	EY–76–C–06–2440

PROJECT SUMMARY:

Background

The project is beginning the third year of a 3-year program to develop, test, and perform prototype applications of a WECS site-selection methodology.

Objective

The primary objective is to provide an improved siting methodology which makes use of mathematical wind field modeling to extrapolate data from measurement locations to other, potentially more windy, sites throughout a meso-scale area.

Approach

The siting methodology is based on the use of a pseudo-potential flow, objective analysis scheme, and a three-dimensional primitive equation boundary layer model. The objective analysis scheme is used to initiate the boundary layer model and to generate wind statistics by calibrating a number of runs corresponding to differing, but typical, boundary conditions. The boundary layer model would be used to give a limited number of detailed "snapshots" of the area in question. These snapshots would correspond to the dominant climatological conditions observed in the area.

Output

All computer codes forming a part of this methodology are to be delineated and thoroughly documented so they can be applied by any competent user. Additionally, the siting methodology is to be documented and demonstrated.

TITLE	ORGANIZATION
Wind Power Studies	Lawrence Livermore Laboratory University of California Livermore, CA 94550
AMOUNT	PRINCIPAL INVESTIGATOR
$ 225,000	D.M. Hardy

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Livermore, CA	12 months—Oct. 1, 1977	UCRL–50034–76

PROJECT SUMMARY:

Objective

The objective of this study is to develop a general method for identifying potential WECS sites within a mesoscale area.

Approach

The methodology involves the combined use of measurements and an objective analysis scheme. Using existing wind measurements, a computer routine is used to identify high wind areas. The current effort is to demonstrate this methodology on the island of Oahu by a combined program of measurement and numerical analysis. Work is also under way to study the use of principal components analysis (using empirical orthogonal eigenfunctions) in site selection. This technique would be used to identify the wind speeds and directions which occur most frequently over an area and to assign probabilities of occurrence to them.

Output

The products are to be included in a report describing the methodology and the computer codes. The report is to contain all documentation required to apply the method.

TITLE	ORGANIZATION
Meteorological Studies for Wind Power	Sandia Laboratories Environmental Research Albuquerque, NM 87115
AMOUNT	PRINCIPAL INVESTIGATOR
$ 50,000	J.W. Reed

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Albuquerque, NM	12 months—Oct. 1, 1977	S189–76–32

PROJECT SUMMARY:

Background

This program began with a national assessment of wind power statistics, completed in 1973. The program has evolved into assessing the long-term reliability of wind power by developing long (5 to 10 years) time series of available wind power at various heights for various locations.

Objective

This study's objectives are to (1) investigate techniques for adjusting wind speeds measured at various heights to a uniform height; (2) examine the time dependent statistics of wind power availability; (3) investigate the availability of wind power for various wind turbine operating parameters; and (4) examine run duration statistics for various wind speed classes.

Approach

Data from 15 National Weather Stations located throughout the country are used in various computer programs which have been developed to assess the seasonal, daily, and long-term variability of wind power. Other programs are used to normalize wind power data to a uniform height for different observed heights.

Output

Reports are to be published summarizing the data processing techniques and describing the analysis techniques and results from the long-term reliability studies.

TITLE	ORGANIZATION
Estimation of Wind Characteristics at Potential Wind Energy Conversion Sites	Battelle—PNL Subcontractors: The Center for the Environment and Man, Inc., Hartford, CT; Geomet, Inc., Gaithersburg, MD, Meteorology, Inc., Altadena, CA; and Stanford Research Institute, Menlo Park, CA
AMOUNT	PRINCIPAL INVESTIGATOR
$ 190,024	David Renné

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Various Sites	7 months—July 1977	EY–76–C–06–1830

PROJECT SUMMARY:

Objective

The objective of these studies is to develop and provide a description of techniques for estimating wind characteristics at a site on the basis of available data at other locations. Estimates of pertinent hub-weight wind characteristics at eight candidate sites for testing of large DOE-sponsored wind machines are to be provided. These sites are: San Gorgonia, CA; Boone, NC; Holyoke, MA; Montauk, NY; Ludington, MI; Russell, KS; Boardman, OR; and Huron, SD.

Approach

Four contractors are applying different estimation, interpolation, or modeling techniques which take into account important variables such as terrain roughness. Extrapolation of data to wind turbine hub height and peak gust analyses will be performed (Subcontractors for this effort include: The Center for the Environment and Man, Inc., Geomet, Inc., Meteorology Research, Inc., and the Stanford Research Institute.

Output

A description of the extrapolation and interpolation techniques are to be provided in final reports. In addition, results of the application of the techniques to the eight candidate sites are to be reported, including frequency duration of wind speed, seasonal and diurnal variability in wind speed, run duration statistics for wind in different speed classes, a peak gust analysis, and a distribution of wind speed with direction.

1.5 TECHNOLOGY DEVELOPMENT

TITLE	ORGANIZATION
Supporting Research and Technology (SR&T) Program	NASA—Lewis Research Center Cleveland, OH 44135
AMOUNT	**PRINCIPAL INVESTIGATOR**
$ 1,950,000	William H. Robbins

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Cleveland, OH	12 months—Oct. 1, 1977	E(49-26)-1028

PROJECT SUMMARY:

Objective

The overall objective of the SR&T program is to develop the technology required to reduce the capital and maintenance costs of wind systems and to improve their performance, reliability, and service life.

Approach

To achieve this task, NASA will continue testing the MOD-0 wind turbine to optimize machine performance and allow evaluation of configuration changes. New concepts in support of the MOD-2 program and low-cost wind turbine programs will be evaluated. The majority of other tasks under effort have been contracted to private industry and are controlled by NASA project management.

Output

Engineering data and design criteria developed under this effort will enable the development of technology which may improve the competitive position of wind energy systems.

TITLE	ORGANIZATION
150-foot Wind Turbine Blade Project	NASA—Lewis Research Center Subcontractor: Kaman Aerospace Corp. Old Windsor Road Bloomfield, CT 06002
AMOUNT	PRINCIPAL INVESTIGATOR
$ 1,917,159	Herbert Gewehr

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Bloomfield, CT	18 month—Feb. 14, 1977	E(49-26)-1028

PROJECT SUMMARY:

Objective

The objective of this project is to design, fabricate, test, and evaluate a potentially low-cost blade for a 300-foot diameter rotor used on a baseline wind turbine. The objective includes providing a technological base for blades of this size and identifying those fundamental characteristics of the blade and design criteria that could be altered to improve both the low-cost potential and technical performance.

Approach

To achieve this objective, a contract for the design, development, fabrication, and test of a representative 150-foot long blade was awarded to Kaman Aerospace Company. The blade spar will be fabricated by Structural Composite Industries, Inc., Azusa, California, under a Kaman subcontract. The spar will be shipped by rail to the Kaman plant for final assembly and testing.

Output

A detailed assessment will be made of the design technology developed under this contract. Test results and fabrication cost analyses are to be developed for various production quantities of the blade.

TITLE	ORGANIZATION
Wood Blade Study	NASA—Lewis Research Center Subcontractor: Gougeon Brothers 706 Martin Street Big City, MI 48706
AMOUNT	PRINCIPAL INVESTIGATOR
$ 36,426	Meade Gougeon

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Cleveland, Ohio	5 months—Nov. 7, 1977	E(49-26)-1028

PROJECT SUMMARY:

Objective

The objective of this study is to determine the feasibility of utilizing epoxy impregnated, laminated wood in the construction of low-cost wind turbine rotor blades.

Approach

To achieve this task a contract was awarded to the Gougeon Brothers, manufacturers of high performance lightweight wooden racing boat hulls, for the analysis, design, and assessment of the technology requirements of low-cost laminated wood wind turbine blades. The contract includes the fabrication of material structure specimens and a representative blade segment that is to be tested and evaluated at Lewis Research Center.

Output

Detailed cost estimates will be provided for various production quantities of the blade.

TITLE	ORGANIZATION
Prestressed Concrete Blade Study	NASA—Lewis Research Center Subcontractor: Tuthill Pump Co. of California 2935 Kerner Blvd. San Rafael, CA 94901
AMOUNT	PRINCIPAL INVESTIGATOR
$ 43,448	Don Furlong

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Los Angeles, CA	4 months—Aug. 29, 1977	E(49-26)-1028

PROJECT SUMMARY:

Objective

The objective of this contract is to determine the feasibility of low-cost wind turbine blades utilizing a prestressed concrete D-spar, fiberglass trailing edge, and commercial grade steel root-end.

Approach

To accomplish this objective, a contract was awarded to the Tuthill Pump Co. with Paragon Pacific, Inc. of Los Angeles, California as subcontractor, for the design, analysis, and assessment of wind turbine blades utilizing prestressed concrete, fiberglass, and steel. The contract includes the fabrication of a 6-foot length of blade to verify the feasibility of the manufacturing technique, and an assessment of the effect of blade weight on wind turbine system design and cost.

Output

A detailed fabrication cost analysis is being performed for procurement of blades in various production quantities.

TITLE	ORGANIZATION
Dynamic Inducer Test Program	AeroVironment, Inc. 145 Vista Avenue Pasadena, CA 91107
AMOUNT	PRINCIPAL INVESTIGATOR
$ 92,988	P.B.S. Lissaman

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Pasadena, CA	10 months—May 16, 1977	EG–77–C–06–1021

PROJECT SUMMARY:

Background

It has been analytically predicted that the power output of a conventional propeller-type wind turbine could be increased by the installation of small high-lift airfoils, called tip vanes, at the tip of each blade.

Objective

The objective of this project is to experimentally verify the predicted effect of small tip vanes in propeller-type wind turbine performance, and estimate the potential cost and cost benefits of the concept.

Approach

To achieve this objective, a number of tip vane units will be designed and tested on a 4.0 meter 2 kilowatt wind turbine, under controlled conditions. The unit is being mounted on a truck so that the natural wind can be simulated and actual power output can be measured for a full range of wind velocities. Using acquired field data, calculations of power output and relative production cost of the tip vane units are being made.

Output

A film provides flow visualization documentation for the experiment. The study is determining the validity of the dynamic inducer concept and providing data to allow an initial estimate of cost-effectiveness.

TITLE	ORGANIZATION
Applied Aerodynamics of Wind Turbines—Aeromechanical Aspects	Oregon State University Department of Mechanical Engineering Corvallis, OR 97331
AMOUNT	PRINCIPAL INVESTIGATOR
$169,425	Robert E. Wilson

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Corvallis, OR	18 months—Aug. 1, 1977	EY–76–S–06–2227

PROJECT SUMMARY:

Objective

The objective of this project is to develop simplified, yet significant engineering analysis techniques for estimating the aerodynamic performance, structural loads, and response of wind turbines of the horizontal axis Darrieus, Savonius, and lift-translator configurations.

Approach

To accomplish this project, simple calculation schemes designed for hand-held calculators are being developed following an analytic review of existing computer models. This review is to consider the aerodynamics and loads of all configurations to be considered as well as the structural dynamics of horizontal and vertical-axis rotors and lift-translator arrays. Information to be provided by the computational schemes will include: (1) the aerodynamic performance and loads associated with rotor operation and yaw, gusting winds, wind shear, and tower shadow; (2) criteria for selection of airfoil section, taper and twist, and the trade-offs among aerodynamic configuration, loading, and performance; (3) treatment of rotor/tower/nacelle dynamics to allow stratightforward physical interpretation; and (4) design analysis of aerodynamic and structural aspects of the Darrieus, Savonius, and lift-translator concepts.

Output

The computational schemes are to be presented in a design handbook which will present the physical basis for the major aerodynamic and structural loads and how they affect wind turbine design.

TITLE	ORGANIZATION
A Preliminary Test Program for the Gedser Wind Turbine	DEFU (The Research Association of the Danish Electricity Supply Undertakings), Lyngby, Denmark
AMOUNT	**PRINCIPAL INVESTIGATOR**
$ 146,000	Mogens Johansson

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Lyngby, Denmark	12 months—Sept. 30, 1977	EG-77-A-01-4104

PROJECT SUMMARY:

Background

The Gedser wind turbine is the only large machine of the previous generation which still exists. It was fabricated in 1957, produced power until 1967 and then stood unused until 1976. The longevity of the Gedser wind turbine offers a unique opportunity to study the performance, structural characteristics and durability of a machine which represents a simpler design philosophy than systems now being developed by DOE. The cost of the project is being shared with DEFU in exchange for use of the data obtained.

Objectives

The primary objectives of this project are to extend the test measurements performed on the Danish Gedser Mill to obtain a better understanding of its aero-mechanical performance and obtain performance and estimated machine life-time data that can be compared with corresponding data obtained from large wind turbines being developed by DOE.

Approach

Instrumentation will be installed to measure critical environment and operation factors, including wind speed and direction, rotor dynamics, torque in shafts and tower vibration. Tests will be performed of the turbine's disassembled components and of the complete rotor system when operational. Field tests will include meteorological measurements, aerodynamic performance, structural response, system dynamic behavior and the quality of electric power produced.

Output

Data provided by the tests of the 3-bladed, fixed-pitch, unwind rotor Gedser machine will be compared with that from the DOE 2-bladed, variable pitch, downwind rotor designs. The results will be used to determine whether aspects of the simpler Gedser design should be considered in planning future U.S. wind turbines.

TITLE	ORGANIZATION
Vertical Axis Wind Turbine Program	Sandia Laboratories Aerodynamics Projects Department Albuquerque, NM 87115
AMOUNT	PRINCIPAL INVESTIGATOR
$1,400,000 (FY78)	Richard H. Braasch

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Albuquerque, NM	12 months—Oct. 1, 1977	AT(29-1)789

PROJECT SUMMARY:

Objective

The program's overall objective is to determine the feasibility of Darrieus vertical-axis wind turbines with blades of the troposkein ("turning rope") configuration.

Approach

To achieve this objective, the program provides these five elements: (1) development of a 17-meter Darrieus unit to acquire experience with fabricating machines of this size, to demonstrate that loads and performance scale with size as predicted, and to serve as a baseline for future low-cost systems; (2) fabrication, by domestic industry, of a potentially marketable, low-cost 17-meter system; (3) testing of 2- and 5-meter Darrieus systems to validate performance evaluation and aeroelastic effects models and to determine requirements for automatic operation; (4) performance of specialty studies in the areas of structures, aerodynamics, and systems; and (5) performance of a parametric optimization of utility grid Darrieus systems to provide estimates of energy cost and to establish guidelines for evaluation of the feasibility of the Darrieus concept.

Output

Experimental systems of 2-, 5-, and 17-meter have been fabricated and are now being tested. A contractor to fabricate one or more 17-meter low-cost systems will be selected in FY 1978. The manufacturing and test data provided by these systems will be analyzed to determine the potential of the Darrieus concept to provide higher performance per unit cost than conventional systems.

TITLE	ORGANIZATION
Vortex Augmentors for Wind Energy Conversion	Polytechnic Institute of New York Aerospace Engineering and Applied Mechanics Brooklyn, NY 11201
AMOUNT	PRINCIPAL INVESTIGATOR
$ 130,150	Pasquale M. Sforza

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Brooklyn, NY	8 months—December 31, 1977	E(49-18)-2358

PROJECT SUMMARY:

Background

The Vortex Augmentor Concept (VAC) has been initially investigated under previous contracts. The device consists of rotors mounted on a delta wing. When the point of the wing is tilted into the wind, compact vortices are created which trail back through the rotors. Potential advantages associated with the VAC include: (1) the ability to use stiffer, smaller, and cheaper rotor blades; (2) reduction of step-up gearbox requirements due to higher rotor rpm; and (3) elimination or reduction of blade pitch control requirements.

Objective

The objectives of this project are to verify the vortex augmentation effects predicted by wind tunnel testing, demonstrate the potential for use of the VAC concept, and estimate machine performance per unit cost.

Approach

A field-test unit is being operated to: (1) determine performance under atmospheric operating conditions, (2) determine machine control parameters, (3) determine a strategy for operational power control, and (4) define economic relationships and design parameters for 10, 100, and 1500 kilowatt VAC machines.

Output

Performance, system control, and economic data provided by the project will enable the determination of the potential of the concept for improved performance per unit cost over conventional systems.

TITLE	ORGANIZATION
Innovative Wind Turbines	West Virginia University Department of Aerospace Engineering Morgantown, WV 26506
AMOUNT	PRINCIPAL INVESTIGATOR
$ 99,931	Richard E. Walters

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Morgantown, WV	7 months—July 1, 1977	EY–76–C–05–5135

PROJECT SUMMARY:

Objective

The project objective is to determine the feasibility of a vertical-axis articulated rotor concept which features circulation control of the blade boundary layer to maximize performance.

Approach

The project is providing theoretical analyses to evaluate test data and provide guidance for scaling the design so that the performance and costs of potential commercial units can be estimated. Tasks include: (1) a performance analysis, exploration of new operational mode concepts, and determination of the influence of boundary layer control on performance; (2) testing various blade configurations; and (3) systems analyses and cost estimates for 100 kW and 1000 kW vertical-axis wind systems.

Output

Performance and cost data will be provided to allow an assessment of the potential of the concept to provide higher performance per unit cost than conventional (propeller-type) wind turbines.

TITLE	ORGANIZATION
Tests and Devices for Wind/Electric Power Charged Aerosol Generator	Marks Polarized Corporation 153-16 Tenth Avenue Whitestone, NY 11357
AMOUNT	PRINCIPAL INVESTIGATOR
$ 99,800	Alvin M. Marks

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Whitestone, NY	12 months—July 1977	EG-77-C-01-4002

PROJECT SUMMARY:

Background

In an aerosol generator, wind forces charged gas particles through a repelling electric field and against collector electrodes, which transmit the resulting high voltage flow of direct current electricity. The basic theory behind this concept has been verified in previous experiments; however, the key technical problem is the development of cost-effective methods of charging and distributing the aerosol.

Objective

The objective of the project is to characterize in detail the operational parameters of five different methods of producing charged particles for electrofluid dynamic wind power generators.

Approach

Under previous grants, a test facility has been developed and four aerosol bench models have undergone testing. The tests on these four methods have led to the evolution of five configurations which are now being studied. Each configuration is being tested, and the measurements are compared with existing analytical predictions. The most promising charging methods are being array-tested in the wind tunnel. If any configurations show potential, a one square-meter prototype will be designed and tested in the atmosphere.

Output

Experimental results will be used to assess the potential of the concept for increased performance per unit cost over conventional systems.

TITLE	ORGANIZATION
Electrofluid Dynamics (EFD) Wind Generators	University of Dayton Research Institute Dayton, OH 45469
AMOUNT	PRINCIPAL INVESTIGATOR
$ 102,264	John E. Minardi

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Dayton, OH	12 months—Sept. 30, 1977	EY-76-S-02-4130

PROJECT SUMMARY:

Background

In an Electrofluid Dynamic (EFD) generator, the wind blows through suitably oriented and charged arrays of electrodes, transporting charged particles against an electrical potential gradient and creating an electric current directly, without moving parts.

Objective

The primary objective is to develop a practical configuration for the EFD wind generator. This includes developing a method for producing suitable quantities of minute particles, extending the study of electrode row designs, and investigating generator performance and economics.

Approach

Work will be conducted under five technical task area. These tasks include: (1) a study of various elcctrode geometrics using a UDRI computer code, (2) a laboratory investigation of two methods of producing suitably-sizcd particles at the required rate, (3) an investigation of two generator geometries using the most promising method developed in task 2, (4) an investigation of two generator geometries capable of producing AC current, and (5) the identification of critical problem areas and possible solutions.

Output

Information and data provided by the project will be used to define a program to enable an early decision on the potential for practical EFD generation.

TITLE	ORGANIZATION
Diffuser Augmented Wind Turbine	Grumman Aerospace Corporation Fluid Dynamics Research Department Bethpage, NY 11714
AMOUNT	PRINCIPAL INVESTIGATOR
$ 203,251	Kenneth M. Forman

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Bethpage, NY	12 months—Sept. 15, 1977	EY–76–C–02–2616

PROJECT SUMMARY:

Background

Diffuser shrouds increase the speed of airflow through a wind turbine by creating a drop in air pressure behind the rotor. They offer the potential for reducing wind power costs by allowing the use of smaller, cheaper blades for a given power output than conventional systems.

Objective

The objective of this project is to refine the design of diffuser and model turbines developed under previous contracts in order to improve confidence in scaling-up designs and increase the productivity-to-cost ratio.

Approach

The ongoing program focuses on continued wind tunnel testing, with the goal of increasing the performance augmentation from 1.5 to 3.0. A more detailed study of boundary layer controlled flows is being performed and the use of design variations to boost performance is being investigated. A 5.5 meter-diameter test model will be designed, and a cost estimate of the machine will be provided.

Output

Performance and economic data for wind tunnel tests will be provided. A preliminary design and complete specifications for the 5.5 meter system will be evaluated. If a decision is made to field-test the unit, the system will be assembled and installed.

TITLE	ORGANIZATION
Technical and Management Support for the Development of Wind Systems for Farm, Remote and Rural Use	DOE Rocky Flats Plant Rockwell International Golden, CO 80401
AMOUNT	PRINCIPAL INVESTIGATOR
$ 1,850,000	Terry Healy

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Golden, CO	36 months—April 12, 1976	E(29–2)–3533

PROJECT SUMMARY:

Background

Federal efforts to assist commercialization of small wind systems will be carried out with the utmost sensitivity to those factors which will help rather than hinder the businesses which develop and market these machines. The Department of Energy's Rocky Flats Plant (managed for DOE by Rockwell) was selected as the most suitable DOE field site for testing and coordinating the activities in this element.

Objective

The primary goal of the program is to reduce the cost of energy generated by small (under 100 kW) wind systems. Specific objectives include the heavily instrumented testing of small systems, the development of advanced small systems, and the dissemination of technical information to small system users.

Approach

This multiphase program calls for performance testing and evaluation of commercially available small machines, the development of advanced, low-cost WTG's in three size ranges, and the investigation of ways to advance the commercialization of wind energy products. Rocky Flats is working with USDA to identify available machines or develop new systems which are competitive with traditional energy sources in specific applications. A program to develop new systems in 1 kW, 8 kW, and 40 kW size ranges has been initiated with the placement of one subcontract in FY 1977 and plans for additional contracts in FY 1978.

Output

A small wind systems test center has been established at Rocky Flats, and eight machines have undergone partial performance and reliability testing. During FY 1978, testing will continue and test data will be made available to the public. A "User's Guide" and indexes of wind energy researchers and available small wind systems will be published.

TITLE	ORGANIZATION
Investigation of the Feasibility of Using Windpower for Space Heating in Colder Climates	DOE Rocky Flats Plant Subcontractor: University of Massachusetts Department of Mechanical Engineering Amherst, MA 01002
AMOUNT	PRINCIPAL INVESTIGATOR
$ 166,556	Dr. Duane Cromack

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Amherst, MA	12 months—July 1, 1977	E(29-2)-3533

PROJECT SUMMARY:

Background

The use of wind power for space heating minimizes the energy storage and interface problems associated with wind power in other applications.

Objective

This project continues an effort to investigate the economic feasibility of heating buildings in colder, windier, cloudier portions of the country using wind energy.

Approach

The solar habitat system at the University of Massachusetts has been equipped with a 32-foot wind turbine which generates power for direct resistance heating. Several alternative configurations are being studied and conceptual designs developed and compared. These include thermal water heating storage, combined wind and flat plate solar, and direct conversion from wind to heat energy by mechanical means. The structural mechanics are being modeled, and characteristics of the approach wind and rotor wake are being measured to determine ways to improve the system's performance per unit cost.

Output

The project will provide an initial verification of the cost and practicality of heating homes by wind power.

TITLE	ORGANIZATION
Development of a 1 kW High Reliability Wind Turbine Generator 3 bladed up-wind (North Wind) 2 bladed downwind (Enertech) 3 bladed Cycloturbine (ASI)	DOE Rocky Flats Plant Subcontractors: North Wind Power Co. Box 315 Warren, Vermont 05674 Enertech P.O. Box 420 Norwich, Vermont 05055 Aerospace Systems, Inc. 1 Vinebrook Park Burlington, Massachusetts 01803
AMOUNT	PRINCIPAL INVESTIGATOR
$ 260,000 (NorthWind) $ 150,000 (Enertech) $ 280,000 (ASI)	Don Mayer (North Wind) Bill Drake (Enertech) Jon Zuara (ASI)

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
See above.	30 months—October 1977	E(29-2)-3533 (Rocky Flats Plant)

PROJECT SUMMARY:

Background

An increasing number of applications for very small wind systems involve rural and remote needs for powering repeater stations, seismic monitoring stations, and offshore navigation aids, as well as for pumping water into remote stock watering tanks. An economical, rugged wind turbine with an output of 1 kW has been identified as ideal for such applications.

Objective

The project objective is to challenge industry to develop the technology needed to produce such a system at a retail cost of about $1500 per installed kW ($77).

Approach

Three contractors will be selected from among respondents to an FY 1977 RFP to design, fabricate, and test such systems. This will be followed by the procurement of a sufficient number of pre-production units to determine firm cost data.
Performance and reliability of the systems will be verified at the Rocky Flats Small WECS Test Center.

Output

The project will provide advanced designs, together with sufficient manufacturing and performance data to verify cost and durability.

TITLE	ORGANIZATION
8 kW Turbine Generator Development 3 bladed downwind (Windworks) 2 bladed downwind, selfadjusting flex-beam rotor (UTRC) 3 bladed Darrieus (Alcoa) 3 bladed downwind (Grumman)	DOE Rocky Flats Plant Subcontractors: Windworks Box 329 Rt. 3 Mukwonago, Wisconsin 53149 United Technologies Research Center Silver Lane East Hartford, Connecticut 06108 Alcoa Aluminum Company of America Labs Alcoa Laboratory Alcoa Center, Pennsylvania 15069 Grumman Corporation Energy Systems Division—Government Operations 4175 Veterans Memorial Highway Ronkonkoma, New York 11777
AMOUNT	PRINCIPAL INVESTIGATOR
$ 388,000 (Windworks) $ 438,000 (UTRC) $ 356,000 (Alcoa) $ 356,000 (Grumman)	Hans Meyer, Windworks M. C. Cheney, Jr., UTRC Bob Stemler, Alcoa Frank Adler, Grumman

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
See above	30 months—October, 1977	E(29-2)-3533 (Rocky Flats Plant)

PROJECT SUMMARY:

Background

The peak demand for an average home without electrical heating is approximately 8 kW. A wind system of this size would have wide application to powering homes or farm buildings.

Objective

The goal of this program is to challenge industry to produce an 8 kW wind system at an initial cost to the user of $750 per installed kW, excluding batteries, inverter, or other secondary components.

Approach

This two-phase program requires: (1) design and analysis of complete systems capable of producing 8 kW in a 20 mph wind and delivery of working drawings, and (2) construction of prototype machines and delivery to Rocky Flats for testing and evaluation.

Output

The project will provide advanced designs, together with sufficient manufacturing and performance data to verify cost and durability.

TITLE	ORGANIZATION
Development of a 40 kW Wind Turbine Generator	DOE Rocky Flats Plant Subcontractor:
AMOUNT	PRINCIPAL INVESTIGATOR

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
	30 months—	E(29–2)–3533 (Rocky Flats Plant)

PROJECT SUMMARY:

Background

While there is a large potential market for wind systems of 40 kW output, no such machine is currently available. Systems of this size could pump deep-well irrigation systems, provide power to small isolated communities, and meet the needs of small factories.

Objective

The project objective is to develop the technology to produce such systems at retail costs attractive to potential users. The cost goal for production units of this system is $500 per installed kW.

Approach

The Rocky Flats Plant will select two contractors from among respondents to an FY 1977 RFP to design, fabricate, and test 40 kW systems. The procurement of a number of pre-production units will determine firm cost data. System performance will be verified at the Rocky Flats Small WECS Test Center.

Output

The project will provide advanced designs, together with sufficient manufacturing and performance data to verify their cost and durability.

TITLE	ORGANIZATION
Development of Rural and Remote Applications of Wind Generated Energy	Agricultural Research Service U.S. Department of Agriculture Beltsville, MD 20705
AMOUNT	PRINCIPAL INVESTIGATOR
$ 590,000	L. A. Liljedahl

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Beltsville, MD	2 years—Jan. 12, 1976	E(49-26)-1026

PROJECT SUMMARY:

Background

The USDA Agricultural Research Service (ARS) is managing projects to test rural and remote applications of wind systems.

Objective

The program objective is to develop agricultural wind power applications to provide useful information and guidance to potential users of wind systems in the rural and remote area market.

Approach

Applications such as irrigation, space heating and ventilation, and agricultural products processing and storage are being tested by private industry, universities, and USDA experiment stations. General studies address the feasibility of using small WECS for various types of rural and remote applications.

Output

Test results will determine the practicality of various applications and provide users with guidelines for implementation. ARS will work with the Rocky Flats test program in the development of wind systems to satisfy identified requirements.

TITLE	ORGANIZATION USDA
Apple Storage Cooling	Virginia Polytechnic Institute and State University (Subcontractor) Department of Aerospace and Ocean Engineering Blacksburg, VA
AMOUNT	PRINCIPAL INVESTIGATOR
$ 242,000 (FY 1975)	J. Schetz

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Blacksburg, VA	24 months—Nov. 1976	E(49–26)–1026 (USDA)

PROJECT SUMMARY:

Objective

The objective of this project is to obtain actual operating data on the performance of a wind turbine used for refrigeration of an apple storage warehouse.

Approach

An appropriately sized wind turbine has been installed and coupled through an appropriate transmission system to the compressor of a refrigeration system for an apple storage warehouse. The wind velocity, ambient temperatures, the cooling supplied to the building, and the cooling load of the building are measured. The measurements are being analyzed to provide empirical performance characteristics of such a system, as a function of environmental conditions and wind velocities.

Output

A report on the experimental study will provide design criteria and procedures.

TITLE	ORGANIZATION
Low-lift Pumping	USDA Subcontractor: Wind Erosion Laboratory USDA—Agricultural Research Service
AMOUNT	PRINCIPAL INVESTIGATOR
$ 66,000 (FY76)	L.J. Hagen

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Manhattan, KS	24 months—Oct. 1976	E(49-26)-1026 (USDA)

PROJECT SUMMARY:

Objective

The objectives of this project are to obtain actual operating data on the performance of a windmill driving a low-lift irrigation pump and to identify operating problems.

Approach

A windmill of approximately 20-foot diameter has been installed and directly coupled, through an appropriate transmission system, to an irrigation pump operating at low-lift. The pumping rate and wind velocities are being recorded to determine performance as a function of wind velocities.

Output

A report of research results will provide design criteria and procedures.

TITLE	ORGANIZATION
Dairy Milk Cooling	USDA Subcontractor: Kaman Sciences Corporation Colorado Springs, CO
AMOUNT	PRINCIPAL INVESTIGATOR
$ 169,000 (FY76)	G. Curtis

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Colorado Springs, CO	—Nov. 1976	E(49–26)–1026 (USDA)

PROJECT SUMMARY:

Objective

The objective of this project is to obtain actual operating data on the performance of a windmill-driven refrigeration system used for dairy milk cooling.

Approach

An appropriately sized wind electric generator has been directly coupled to an electrically-driven dairy milk cooler used in a typical dairy farm. The wind velocity, the electric power generated and used, and the refrigeration work performed are being recorded. The overall performance of this system is being estimated as a function of the wind velocity distribution, the operating characteristics of this system, and the amount of intermediate refrigeration storage used.

Output

A report of the experimental study will provide information to allow assessment of the practicality of the concept.

TITLE	ORGANIZATION
Direct Hydraulic Dissipation to Heat	USDA Subcontractor: Cornell University Ithaca, NY
AMOUNT	PRINCIPAL INVESTIGATOR
$ 175,000 (FY76)	W.W. Gunkel

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Ithaca, NY	36 months—March 1977	E(49-26)-1026 (USDA)

PROJECT SUMMARY:

Objective

The objectives of this project are to obtain performance data on a system converting wind power to heat through hydraulic dissipation and to identify operating problems.

Approach

A hydraulic churn for energy dissipation is directly coupled to an appropriately sized vertical axis rotor. The wind velocity and heat production are being measured. Analysis of the measurements will provide heat yield and conversion efficiency as a function of wind velocity.

Output

A report of the experimental study will provide information to allow an assessment of the concept's practicality.

TITLE	ORGANIZATION: NASA—Lewis Research Center
Experimental Wind Energy Systems for Early User Applications (MOD–OA Project)	Westinghouse Elec. Corp. (Subcont.-System) Industry Serv. Div., Pittsburg, PA 15220 Lockheed Aircraft Corp. (Subcont.—Blade) P.O. Box 33, Ontario, CA 91716
AMOUNT	PRINCIPAL INVESTIGATOR
$ 1,100,000	System: John Cerminara Blade: Charles Hunnicut

WORK LOCATION: Clayton, NM; Block Island, RI; and Culebra, PR	DURATION-AWARD DATE 12 months—Oct. 1, 1977	CONTRACT NO. E(49–26)–1004 (NASA)

PROJECT SUMMARY:

Objective

The objective of this project is to conduct early testing of wind turbines in a user environment to determine machine operating, performance and dynamic characteristics, and the economics of large utility-based wind systems.

Approach

The prototype Model–0 design has been simplified, made field-worthy, and uprated to 200 kilowatts. Westinghouse Electric Company and Lockheed have been selected to fabricate the machine and blades for installation at three sites chosen from among 17 utility company sites during 1976 through 1977. The first machine will be tested at Clayton, New Mexico beginning in late 1977. Experimental machines will also be installed at Block Island, Rhode Island and the Island of Culebra, Puerto Rico.

Output

The field tests will provide valuable data and information to allow optimization of wind turbine design features for durable and economical operation. Utility operation of the machines will enable identification of electrical system stability and control requirements, and the institutional issues and other requirements involved in the implementation of large-scale, utility-based wind systems.

TITLE	ORGANIZATION: NASA—Lewis Research Center
MOD–1 2-Megawatt Wind System	Subcontractor: General Electric Co. Space Division P.O. Box 8661 Philadelphia, PA 19101
AMOUNT	PRINCIPAL INVESTIGATOR
$ 5,800,000	R.J. Barchet

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Boone, NC	12 months—Oct. 1, 1977	E(46–26)–1010 (NASA)

PROJECT SUMMARY:

Objective

The primary objectives of the project are to: (1) determine the operating and economic characteristics of a utility-operated, megawatt-scale wind turbine; (2) involve industry in the design, fabrication, and installation of large wind systems; and (3) involve potential users of wind systems (such as utilities) so that institutional, operational, and technical interface requirements can be clearly defined.

Approach

General Electric has been selected as the primary contractor to develop a 2-megawatt, horizontal-axis, propeller-type experimental wind turbine generator with a rotor 208 feet in diameter. The system will be optimized for 18 mph average wind sites. One MOD–1 experimental wind turbine generator will be fabricated and installed at Boone, North Carolina during 1978.

Output

Field-testing of the turbine will provide engineering and performance data for use in refining the design features of future systems and will contribute valuable information to wind energy applications and multi-unit systems studies. This system will form a basis for conquering the technical, economic, and operational questions associated with wind power for utility use.

TITLE	ORGANIZATION
MOD–2 Project	NASA—Lewis Research Center Subcontractor: Boeing Engineering and Construction P.O. Box 3999 Seattle, WA 98124
AMOUNT	PRINCIPAL INVESTIGATOR
$ 1,063,000	William I. Ratcheson

WORK LOCATION	DURATION-AWARD DATE	CONTRACT NO.
Seattle, WA	12 months—Oct. 1, 1977	E(49–26)–1059 (NASA)

PROJECT SUMMARY:

Background

Most areas of the United States do not have adequate average wind speeds (18–24 mph) to allow current large wind systems to achieve their maximum energy output for extended periods. To increase the area available for wind energy conversion, a megawatt-scale system optimized to lower wind speed sites is required.

Objective

The project objectives are to determine if wind turbines with nominal 300-foot diameter rotors will be more cost-effective at moderate (14 mph) wind sites than the smaller 200-foot MOD–1 system, and to identify and solve problems associated with building turbines in a size regime that is new from a construction standpoint.

Approach

NASA is managing a project contracted to Boeing Engineering and Construction which will: (1) establish a preliminary design for the MOD–2; (2) determine the cost-sensitivity of large rotors; (3) update cost estimates concurrently with a detailed NASA/DOE design review; and (4) following approval of the design, fabricate and assemble the wind turbine(s) for installation on a selected user site(s).

Output

One or more MOD–2 systems will be fabricated and installed for testing. Design and cost information and performance models for very large wind systems will be provided.

SELECTED REPORTS BIBLIOGRAPHY

The entries in this partial bibliography include those final, or other useful, self-contained reports generated by the Federal program as of November 1, 1977. These reports are available from The National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, (703) 557–4650 and/or The Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, (202) 783–3238. Many progress or partial-year reports are also available, and numerous additional final reports will be published in the coming months. Report identification numbers are listed in parentheses at the end of each entry.

MISSION ANALYSIS AND GENERAL REPORTS

Energy Research and Development Administration. *Federal Wind Energy Program, Summary Report,* January 1, 1977, 56 pp. U.S. Government Printing Office. (Stock No. 060–000–00048–4)

Energy Research and Development Administration. *Federal Wind Energy Program, Summary Report.* Division of Solar Energy, October, 1975, 78 pp. (ERDA–84)

General Electric, Space Division. *Wind Energy Mission Analysis,* February, 1977. Contract No. E(11–1)–2578. Executive Summary: COO/2578–1/1, 2 pp.; Final Report: COO/2578–1/2, 219 pp. Appendices A–J: COO/2578–1/3, 480 pp.

JBF Scientific Corporation. *Summary of Current Cost Estimates of Large Wind Energy Systems* (Special Technical Report), February, 1977, 62 pp. Contract No. E(49–18)–2364. (DSE/2521–1)

Lockheed California Company. *Wind Energy Mission Analysis,* October, 1976; Contract No. EY–76–C–03–1075. Executive Summary: SAN/1075–1/3, 30 pp.; Final Report: SAN/1075–1/1; Appendix: SAN/1075–1/2.

Mitre Corporation. *Wind Energy Conversion Systems, Proceeding of the Second Workshop* (on June 9–11, 1975). F.R. Eldridge, June, 1975, 536 pp. Contract No. NSF–AER–75–12937. (NSF–RA–N–75–050)

————. *Wind Machines.* F.R. Eldridge, October, 1975, 84 pp. (NSF–RA–N–75–051) U.S. Government Printing Office. (Stock No. 038–000–00272–4)

NASA-Lewis Research Center. *Wind Energy Conversion Systems, Workshop Proceedings* (Washington, D.C. June 11–13). J.M. Savino, December, 1973, 258 pp. Grant No. NSF–AG465. (NSF–RA–N–73–006) (PB 231 341)

————. *Wind Energy Utilization, A Bibliography.* Technical Applications Center, University of New Mexico, for NASA–LeRC. (TACW–75–700)

APPLICATIONS OF WIND ENERGY

Michigan State University, Division of Engineering Research, *Application Study of Wind Power Technology to the City of Hart, Michigan.* J. Asmussen, P.D. Fisher, G.L. Park, O. Krauss, December, 1975, 103 pp. Contract No. E(11–1)–2603. (COO–2603–1)

NASA-Lewis Research Center. *Benefit-Cost Methodology Study with Example Application of the Use of Wind Generators.* R.P. Zimmer, C.G. Justus, R.N. Mason, S.L. Robinette, P.G. Sassone, W.A. Schaffer of Georgia Institute of Technology, July 1975, 411 pp. (NASA CR–134864)

LEGAL/SOCIAL/ENVIRONMENT ISSUES

Battelle Memorial Institute, Columbus Laboratories. *An Evaluation of the Potential Environmental Effects of Wind Energy Systems Development* (Final Report). S. Rogers, et. al., August, 1976. Contract No. NSF–AER–75–07378. (ERDA/NSF/07378–75/1)

George Washington University. *Legal-Institutional Implications of Wind Energy Conversion Systems, Final Report.* L.H. Mayo, et. al., September, 1977, 333 pp. Contract No. APR 75–19137. (NSF/RA–770204)

Michigan, University of. Radiation Laboratory *TV and FM Interference by Windmills* (Final Report). T.B.A. Senior, et. al., February, 1977, 150 pp. Contract No. EY–76–S–02–2846. (COO/2846–76/1)

Societal Analytics Institute, Inc. *Barriers to the Use of Wind Energy Machines: The Present Legal/Regulatory Regime and a Preliminary Assessment of Some Legal/Political/Societal Problems.* R.F. and H.J. Taubenfeld, July, 1976, 159 pp. Contract No. NSF–AER75–18362. (PB–263 567)

WIND CHARACTERISTICS

Alaska, University of, Geophysical Institute. *Study of Alaskan Wind Power and Its Possible Applications* (Final Report, May 1, 1974–January 30, 1976). T. Wentink, Jr., February, 1976, 139 pp Contract No. NSF–AER–74–00239 (NSF/RANN/SE/AER–74–00239) (PB 253 339)

Alaska, University of, Geophysical Institute, *Wind Power Potential of Alaska. Part II, Wind Duration Curve Fits and Output Power Estimates for Typical Windmills.* T. Wentink, Jr., August, 1976, 86 pp. Contract No. E(45–1)–2229. RLO/2229/T12–16/1)

Battelle-Pacific Northwest Laboratories. *Annual Report of the Wind Characteristics Program Element for the Period April 1967–June 1977.* J.V. Ramsdell, June, 1977. Contract No. EY–76–C–06–1830. (BNWL–2220–WIND–10)

Colorado State University. *Sites for Wind Power Installations: Wind Tunnel Simulation of the Influence of Two-dimensional Ridges on Wind Speed and Turbulence* (Annual Report). R.N. Meroney, et. al., July, 1976, 80 pp. Contract No. NSF–RANN–GAER–75–00702. (ERDA/NSF/00702 75/1)

Georgia Institute of Technology. *Reference Wind Speed Distributions and Height Profiles for Wind Turbine Design and Performance Evaluation Applications.* C.G. Justus, W.K. Hargraves, A. Mikhail, August, 1976, 96 pp. Contract No. E(40–1)–5108. (ORO/5108–76/4)

———. *Wind Energy Statistics for Large Arrays of Wind Turbines (New England and Central U.S. Regions).* C.G. Justus, August, 1976, 129 pp. Contract No. NSF–AER75–00547. (PB 260 679)

NOAA-National Climatic Center. *Initial Wind Energy Data Assessment Study.* M.J. Changery, May, 1975, 132 pp. Contract No. NSF–AG–517. (NSF–RA–N–75–020) (PB 244 132)

Sandia Laboratories. Contract No. S189–76–32:

Wind Energy Potential in New Mexico. J.W. Reed, R.C. Maydew, B.F. Blackwell, July, 1974, 40 pp. (SAND74–0071)

Wind Power Climatology. J.W. Reed, December 1974. (SAND74–0435)

Wind Power Climatology of the United States. J.W. Reed, May, 1975 163 pp. (SAND74–3078)

TECHNOLOGY DEVELOPMENT

General Electric, Space Division. *Design Study of Wind Turbines 50 kW to 3000 kW for Electric Utility Applications.* December, 1976. Volume I (Summary Report): NASA CR–134934; Volume II: NASA–CR–134035; Volume III: NASA CR–134936.

Lockheed-California Company. *100 kW Metal Wind Turbine Blade Basic Data, Loads, and Stress Analysis.* A.W. Cherritt and J.A. Gaidelis, June, 1975. NASA Contract No. NAS3–19235. (NASA CR–134956)

————. *100 kW Metal Wind Turbine Blade Dynamics Analysis, Weight/ Balance and Structural Test Results.* W.D. Anderson, June, 1975. NASA Contract No. NAS3–19235 (NASA CR–134957)

Martin Marrietta Laboratories. *Segmented and Self-Adjusting Wind Turbine Rotors* (Final Report). P.F. Jordon, R.L. Goldman, April, 1976, 113 pp. Contract No. EY–76–C–02–2613. (COO/2613–2)

Massachusetts Institute of Technology. *Research on Wind Energy Conversion Systems.* R.H. Miller, December, 1976. Contract No. NSF–AER–75–00826

NASA-Lewis Research Center. Interagency Agreement No. E(49–26)–1028:
Free Vibrations of the ERDA-NASA 100 kW Wind Turbine. C.C. Chamis, T.L. Sullivan, February, 1976. (NASA TM X–71879)

Transient Analysis of Unbalanced Short Circuits of the ERDA–NASA 100 kW Wind Turbine Alternator. H.H. Hwang, Leonard J. Gilbert, July, 1976. (NASA TM X–73459)

Early Operation Experience on the ERDA/NASA 100 kW Wind Turbine. J.C. Glasgow, B.S. Linscott, September, 1976. (NASA TM X–71601)

Tower and Roter Blade Vibration Test Results for a 100 Kilowatt Wind Turbine. B.S. Linscott, W.R. Shapton, D. Brown, October, 1976. (NASA TM X–3426)

Wind Tunnel Measurements of the Tower Shadow on Models of the ERDA/ NASA 100 kW Wind Turbine Tower. J.M. Savino and L.H. Wagner, November, 1976. (NASA TM X–73548)

Synchronization of the ERDA–NASA 100 kW Wind Turbine Generator with Large Utility Networks. H.H. Hwang and L.J. Gilbert, March, 1977, 17 pp. (NASA TM X–73613)

Vibration Characteristics of a Large Wind Turbine Tower on Non-Rigid Foundations. S.T. Yee, T. Yung, P. Change, et. al. May, 1977. (ERDA/ NASA 1004–77/1)

Dynamic Blade Loading in the ERDA/NASA 100 kW and 200 kW Wind Turbines. D.A. Spera, D.C. Janetzke, T.R. Richards, May, 1977. (ERDA/ NASA 1004–77/2)

Drive Train Normal Modes Analysis for the ERDA/NASA 100-Kilowatt Wind Turbine Generator. T.L. Sullivan, D.R. Miller, D.A. Spera, July, 1977. (ERDA/NASA/1028–77–1)

Investigation of Excitation Control for Wind Turbine Generator Stability. V.D. Gebben, August, 1977. (ERDA/NASA 1028–77/3)

Nastran Use for Cyclic Response and Fatigue Analysis of Wind Turbine Towers. C.C. Chamis, P. Manos, J.H. Sinclair, J.R. Winemiller, October, 1977, 20 pp. (ERDA/NASA 1004–77/3)

Oklahoma State University. *Development of an Electrical Generator and Electrolysis Cell for a Wind Energy Conversion System* (Final Report, July 1, 1973–July 1, 1975). W. Hughes, H.J. Allison, R.G. Ramarkumar, July, 1975, 280 pp. Contract No. NSF–AER–75–00647. (NSF/RA/N–75–043) (PB 243 909)

Oregon State University. *Applied Aerodynamics of Wind Power Machines.* R.E. Wilson, P.B.S. Lissaman, July, 1974, 116 pp. Contract No. NSF–AER–74–04014 A03. (PB 238 595)

Oregon State University. *Aerodynamic Performance of Wind Turbines.* R.E. Wilson, P.B.S. Lissaman, S.N. Walker, June, 1976, 170 pp. Contract No. NSF–AER–74–04014 A03. (PB 259 089)

Paragon Pacific, Inc. *Coupled Dynamics Analysis of Wind Energy Systems,* February, 1977. NASA Contract No. NAS3–197707. (NASA CR–135152)

United Technologies Research Center. *Self-Regulating Composite Bearingless Wind Turbine* (Final Report, June 3, 1975–June 2, 1976). M.C. Cheney; P.A.M. Spierings, September 1976, 62 pp. Contract No. EY–76–C–02–2614. (COO/2614–76/1). Executive Summary, 13 pp. (COO/2614–76/2)

ADVANCED SYSTEMS

AAI Corporation and Institute of Gas Technology. *Production of Methane Using Offshore Wind Energy.* R.B. Young, A.F. Tiedeman, Jr., T. G. Marianawski, E.H. Camara, November, 1975. Contract No. NSF–C993. Final Report: (PB 252 307), 131 pp. Executive Summary: (PB 252 308), 29 pp.

Dayton, University of, Research Institute. *Electrofluid Dynamic (EFD) Wind Driven Generator.* J.E. Minardi, M.O. Lawson, G. Williams, October, 1976. Contract No. EY–76–S–02–4130.

Grumman Aerospace Corporation. *Investigation of Diffuser-Augmented Wind Turbines.* R.A. Oman, January, 1977. Contract No. EY–76–C–02–2616. Executive Summary: (COO/2616–1). Technical Report: (COO/2616–2).

McDonnell Aircraft Co. *Feasibility Investigation of the Gyromill for Generation of Electrical Power.* R.V. Brulle, November, 1975, 155 pp. Contract No. E(11–1)–2617 (COO–2617–75/1)

Princeton University. *Optimization and Characteristics of a Sailwing Windmill Rotor.* M.D. Maughmer, March, 1976. Contract No. GI–41891. (NSF/RANN/GI–41891/FR/75/4)

Sandia Laboratories. Contract No. AT(29–1)–789 (Cont.):

Vertical-Axis Wind Turbine Technology Workshop (held at Sandia Laboratories, Albuquerque, New Mexico, May 18–20, 1976). L. Wetherholt, July, 1976, 439 pp. (SAND76–5586)

The Vertical-Axis Wind Turbine-How it Works. B.F. Blackwell, April, 1974, 8 pp. (SLA–74–0160)

Blade Shape for a Troposkien Type of Vertical-Axis Wind Turbine. B.F. Blackwell, G.E. Reis, April, 1974, 24 pp. (SLA–74–0154)

An Electrical System for Extracting Maximum Power from the Wind. A.F. Veneruso, December, 1974, 29 pp. (SAND74–0105)

Some Geometrical Aspects of Troposkiens as Applied to Vertical-Axis Wind Turbines. B.F. Blackwell, G.E. Reis, March, 1975. (SAND74–0177)

Practical Approximations to a Troposkien by Straight-Line and Circular-Arc Segments. G.E. Reis, B.F. Blackwell, March, 1975, 34 pp. (SAND74–0100)

Wind Energy-A Revitalized Pursuit. B.F. Blackwell, L.V. Feltz, March, 1975, 16 pp. (SAND75–0166)

An Investigation of Rotation-Induced Stresses of Straight and of Curved Vertical-Axis Wind Turbine Blades. L.V. Feltz, B.F. Blackwell, March, 1975, 20 pp. (SAND74–0379)

Application of the Darrieus Vertical-Axis Wind Turbine to Synchronous Electrical Power Generation. J.F. Banas, E.G. Kadlec, W.N. Sullivan, March, 1975, 14 pp. (SAND75–0165)

Nonlinear Stress Analysis of Vertical-Axis Wind Turbine Blades. W.I. Weingarten, R.E. Nickell, April, 1975, 20 pp. (SAND74–0378)

Methods of Performance Evaluation of Synchronous Power Systems Utilizing The Darrieus Vertical-Axis Wind Turbine. J.F. Banas, E.G. Kadlec, W.N. Sullivan, April, 1975, 22 pp. (SAND75–0204)

The Darrieus Turbine: A Performance Prediction Model Using Multiple Streamtubes. J.H. Strickland, October, 1975. (SAND75–0431)

Sandia Laboratories. Contract No. AT(29-1)-789—(Cont.):

Engineering of Wind Energy Systems. J.F. Banas, W.N. Sullivan, January, 1976. (SAND75-0530)

Wind Tunnel Performance Data for the Darrieus Wind Turbine with NACA-0012 Blades. B.F. Blackwell, L.V. Feltz, R.E. Sheldahl, 1976. (SAND76-0130)

Wind Tunnel Performance Data for Two- and Three-Cup Savonius Rotors. B.F. Blackwell, L.V. Feltz, R.E. Sheldahl, July, 1977, 108 pp. (SAND76-0131)

Engineering Development Status of the Darrieus Wind Turbine. B.F. Blackwell, W.N. Sullivan, R.C. Reuter, J.F. Banas, March, 1977, 68 pp. (SAND76-0650)

Darrieus Vertical-Axis Wind Turbine Program at Sandia Laboratories. E.G. Kadlec, August, 1976, 11 pp. (SAND76-5712)

Status of the ERDA/Sandia 17-metre Darrieus Turbine Design B.F. Blackwell, September, 1976, 16 pp. (SAND76-5683)

West Verginia University. *Innovative Wind Machines* (Executive Summary and Final Report). R.E. Walters, et. al., June, 1976, Contract No. EY-76-C-05-5135 (ERDA/NSF/00367-76/2)

FARM AND RURAL USE (SMALL) SYSTEMS

Colorado State University. *Wind-Powered Aeration for Remote Locations* (Final Report, March 15, 1975-August 31, 1976). P.M. Schierholz, October, 1976, 130 pp. Contract No. NSF-G-AER-75-00833. (ERDA/NSF/00833-75/1)

Institute of Gas Technology. *Wind-Powered Hydrogen-Electric Systems for Farm and Rural Use.* J.B. Pangborn, April, 1976, 158 pp. Contract No. NSF-AER-75-00772. (PB 259 318)

Massachusetts, University of, Amherst. *Investigation of the Feasibility of Using Windpower for Space Heating in Colder Climates.* (Third quarterly progress report covering the final design and mfg. phase of the project, September-December, 1975). W.E. Heronemus, December, 1975, 165 pp. Contract No. NSF-AER-75-00603. (ERDA/NSF/00603-75/T1)

NASA-Lewis Research Center. *Installation and Initial Operation of a 4100 Watt Wind Turbine.* H.B. Tryon, T. Richards, December, 1975. (NASA TM X-71831)

100 KILOWATT-SCALE SYSTEMS

NASA-Lewis Research Center:

Preliminary Design of a 100 kW Turbine Generator. R.L. Puthoff, P.J. Sirocky, 1974, 22 pp. (NASA TM X-71585; E-8037) (N-74-31527)

Structural Analysis of Wind Turbine Rotor for NSE-NASA MOD-O Windpower System. D.A. Spera, March, 1975, 39 pp. (NASA TM X-3198; E-8133) (N-75-17712)

Plans and Status of the NASA-Lewis Research Center Wind Energy Project. R. Thomas, R. Puthoff, J. Savino, W. Johnson, 1975, 31 pp. (NASA TM X-71701; E-8309) (N-75-21795)

A 100 kW Experimental Wind Turbine: Simulation of Starting Overspeed and Startdown Characteristics. L. Gilbert, February, 1976. (NASA TM X-71864)

Large Experimental Wind Turbines-Where We Are Now. R.L. Thomas, March, 1976. (NASA TM X-71890)

NASA-Lewis Research Center (Cont.):

Fabrication and Assembly of the ERDA/NASA 100 kW Experimental Wind Turbine. R.L. Puthoff, April, 1976. (NASA TM X–3390)

Design Study of Wind Turbines 50 kW to 3000 kW for Electric Utility Applications (See Technology Development).

MEGAWATT-SCALE SYSTEMS

General Electric, Space Division. Design Study of Wind Turbines 50 kW to 3000 kW for Electric Utility Applications (See Technology Development).

NASA-Lewis Research Center. *Large Experimental Wind Turbines.* (See 100 kW-Scale Systems)

INDEX BY NAME OF CONTRACTOR FOR ONGOING PROJECTS

APPENDIX ON UNSOLICITED PROPOSAL REQUIREMENTS

SOLAR recognizes that the unsolicited proposal is a valuable means by which unique or innovative methods or approaches can be made available in developing energy technology. Unsolicited proposals are offered in the hope that SOLAR will enter into a contract with the offeror for researching, developing, or providing services indicated within the proposal. These proposals should not be merely an advance proposal for a specific requirement which would normally be procured by competitive methods.

It is SOLAR's policy to encourage and foster the submission of unsolicited proposals. Since the preparation of an unsolicited proposal represents a substantial investment of time and effort by the offeror, organizations, or individuals who are interested in submitting an unsolicited proposal are encouraged to make preliminary inquiries relating to SOLAR's needs before expending extensive effort in preparing a detailed unsolicited proposal.

Favorable evaluation of an unsolicited proposal is not, in itself, sufficient justification for SOLAR to enter into contract with the offeror. Generally, any unsolicited proposal that (a) is available to the Government without restriction from another source, (b) closely resembles that of a pending competitive solicitation, or (c) is not sufficiently unique to justify acceptance, is unacceptable and must be rejected. Individuals and organizations may submit unsolicited proposals at any time to SOLAR. Proposals related to solar energy programs may be submitted to:

Division of Solar Technology
Office of the Director
U.S. Department of Energy
Washington, D.C. 20545

Since unsolicited proposals may form the basis for technical evaluation or contract negotiations, each should contain detailed information on the purpose and objective of the proposed work; an indication of the offeror's background and previous experience; a concise statement of work; information relating to organization, facilities, and qualifications; other pertinent data; and a detailed cost estimate.

Because of the great degree of interest in solar energy programs and the similarities among many proposed concepts and research and development ideas (which preclude funding them on an unsolicited basis), most projects are supported as a result of solicitations. Solicitation mechanisms used by SOLAR include:

a. *Requests for Proposals.* Requests for Proposals (RFP) are used to contract for a specific scope of work.

b. *Program Research and Development Announcements.* The Program Research and Development Announcements (PRDA) are used to solicit proposals where a specific need is not sufficiently definable to use the traditional RFP process.

c. *Program Opportunity Notices.* The Program Opportunity Notises (PON) are used for technological demonstrations where the objective is the acceleration of commercial application of new energy technologies and systems.

By their very nature, demonstration projects for solar energy technology do not lend themselves to consideration on an unsolicited basis. In addition, innovative concepts submitted on an unsolicited basis should promise a clear benefit to the solor energy program by offering a potential for improvement in cost or performance over other approaches.

Additional information on proposal preparation may be found in:

a. *Guide for the Submission of Research and Development Proposals by Individuals and Organizations,* available at no cost from DOE, Division of Procurement, Washington, D.C. 20545.

b. *Guide for the Submission of Research Proposals from Educational Institutions,* available at no cost from DOE, Office of University Programs, Washington, D.C. 20545.

c. *Guide for the Preparation of Proposals for Special Projects in Energy Education and Training,* available at no cost from DOE, Office of Public Affairs, Educational Programs Branch, Washington, D.C. 20545.

Procurement regulations containing additional information concerning contracting policy and procedures are available at nominal cost from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

Note to Inventors:

The National Bureau of Standards operates a program to evaluate all promising energy-related inventions, particularly those submitted by inventors and small companies. If you have an innovative idea for a wind system, you are encouraged to contact:

Office of Energy-Related Inventions
National Bureau of Standards
Washington, D.C. 20234

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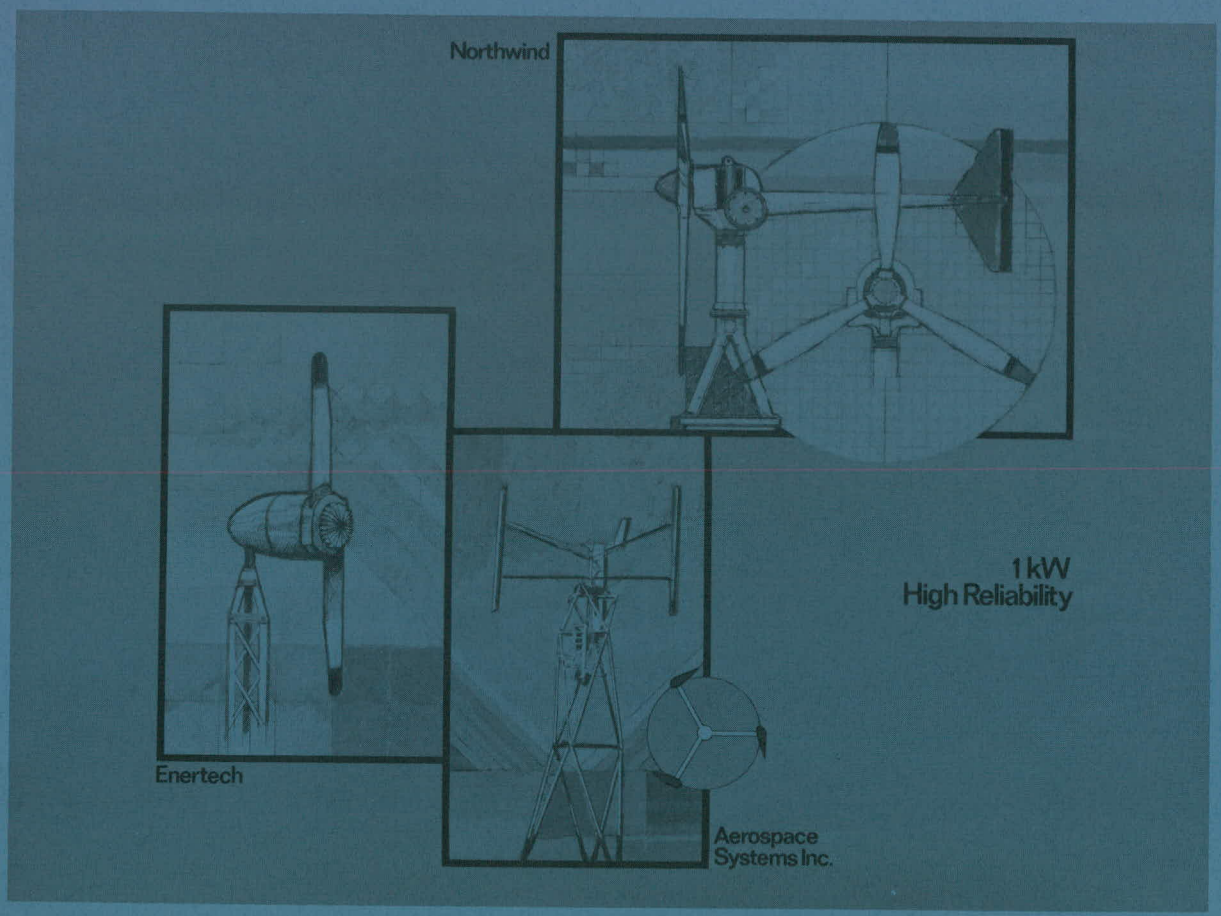

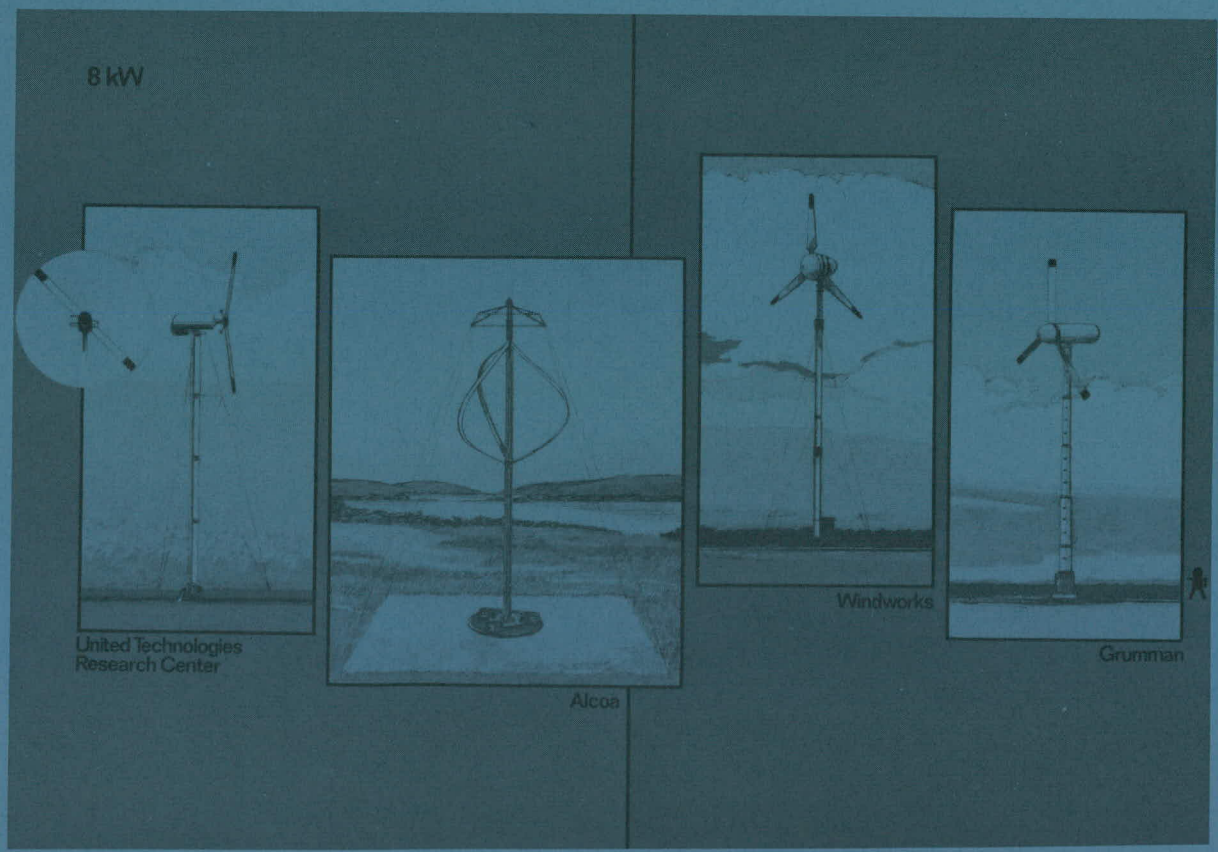

Artist's conceptions of 1 kilowatt and 8 kilowatt wind turbines to be developed and tested under projects managed by the DOE Rocky Flats Plant