SERI/PR-35-356

Draft

Wind Energy Systems Quarterly Review April 1, 1979 – June 30, 1979

Prepared for the
U.S. Department of Energy
Division of Solar Technology
Under Contract No. EG-77-C-01-4041

SERI

Solar Energy Research Institute
1536 Cole Boulevard
Golden, Colorado 80401
A Division of Midwest Research Institute

NOTICE

SERI/PR-35-356

WIND ENERGY SYSTEMS
QUARTERLY REVIEW
APRIL 1, 1979-JUNE 30, 1979

AUGUST 21, 1979

SOLAR ENERGY RESEARCH INSTITUTE
1536 COLE BOULEVARD
GOLDEN, COLORADO 80401
A DIVISION OF MIDWEST RESEARCH INSTITUTE

PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
DIVISION OF SOLAR TECHNOLOGY
UNDER CONTRACT NO. EG-77-C-01-4042

Foreword

The Quarterly Review for the Wind Energy Systems (WES) Program is a visual presentation prepared by the Solar Energy Research Institute (SERI) as an overview of the efforts in the program. This Quarterly Review is delivered to fulfill SERI's Annual Operating Plan (AOP) reporting requirements. The Review presents the objectives, accomplishments, activities, and outputs of each of the tasks in the WES program.

Distribution of this report is limited to those directly involved in this Project as defined by DOE. The Review is prepared for DOE by the staff of the Solar Energy Research Institute, A Division of the Midwest Research Institute (MRI) under Contract No. EG-77-C-01-4042.

REPORT NO. SERI/PR-35-356
DATE: AUGUST 1979
PROGRAM: WIND ENERGY SYSTEMS
TASK: 3520
CONTRACT: EG-77-C-01-4042
START DATE: OCTOBER 1978
COMPLETION DATE: CONTINUOUS
CONTRACTOR: SOLAR ENERGY RESEARCH INSTITUTE
1536 COLE BOULEVARD
GOLDEN, COLORADO 80401

APPROVED FOR:
SOLAR ENERGY RESEARCH INSTITUTE

DENNIS COSTELLO,
ACTING ASSISTANT DIRECTOR

NEIL H. WOODLEY
BRANCH CHIEF
SYSTEMS ANALYSIS

IRWIN E. VAS
PROGRAM COORDINATOR

Agenda

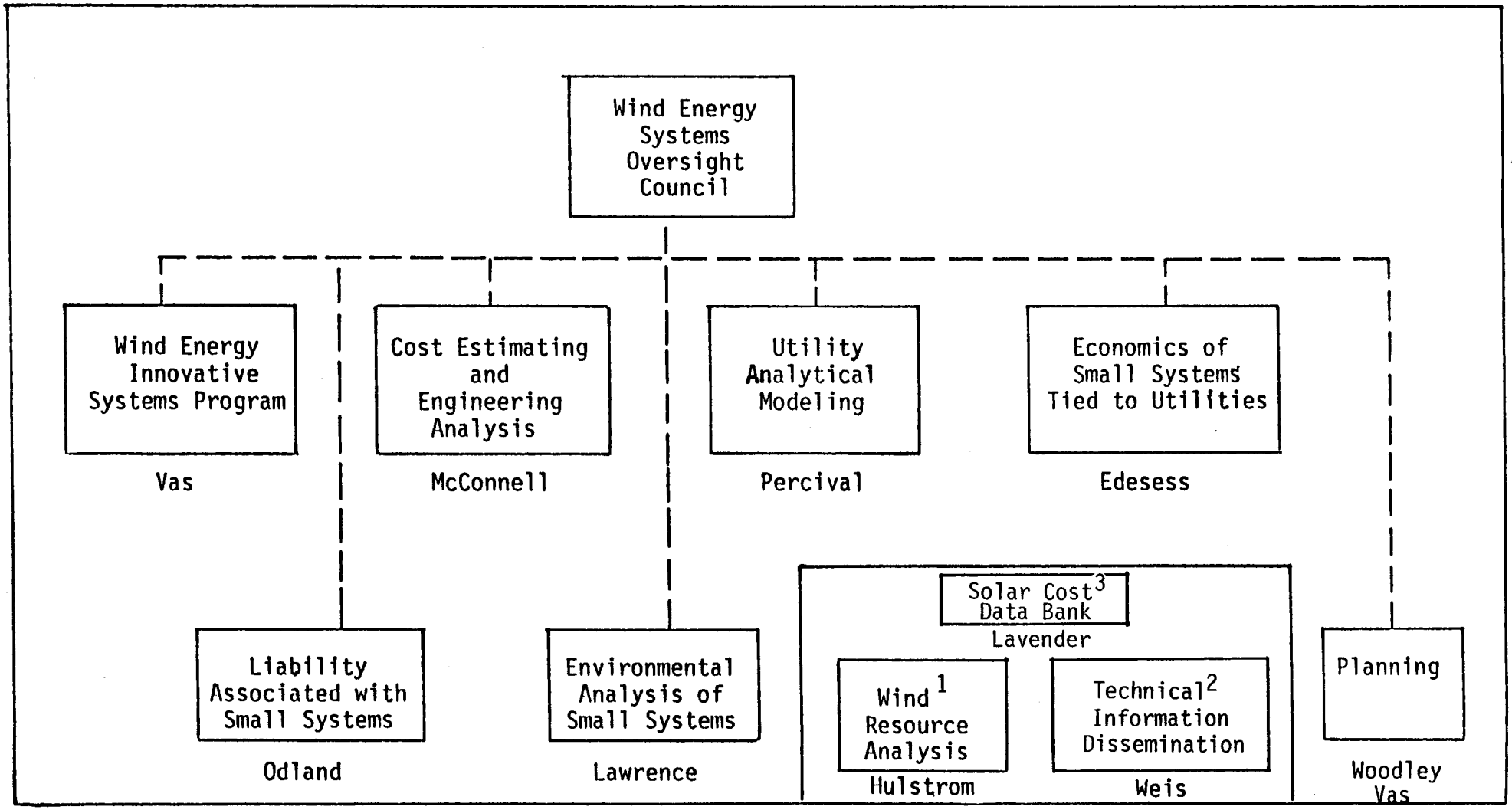
PROGRAM OVERVIEW

IRWIN E. VAS

A TOTAL OF SEVEN TASKS ARE CURRENTLY IDENTIFIED IN THE WIND ENERGY SYSTEM PROGRAM AREA 3.

THREE ADDITIONAL WIND ENERGY RELATED TASKS ARE CARRIED OUT IN OTHER PROGRAM AREAS.

WIND ENERGY RELATED TASKS



[1] Basic and Applied Research - (Program Area 14)

[2] Commercialization Activities - (Program Area 18)

[3] Solar Cost Data Bank (Program Area 10)

THE OVERSIGHT COUNCIL IS COMPRISED OF:

NEIL WOODLEY	CHAIRMAN
IRWIN VAS	PROGRAM COODINATOR
IRWIN VAS	PROGRAM MANAGER
ROBERT LORMAND	
KATHERYN LAWRENCE	
ROBERT MCCONNELL	
ROBERT ODLAND	
JON VEIGEL	
PATRICIA WEIS	

WIND ENERGY INNOVATIVE SYSTEMS

Irwin Vas

Objective

Determine technical and economic feasibility of Innovative Wind Energy systems.

Accomplishments

Completed technical and cost reviews and rank ordered the proposals received in response to RFP RH-9-8085 entitled "Advanced and Innovative Wind Energy Concept Development".

Completed technical reviews of three unsolicited proposals.

Awarded a contract to Grumman Aerospace Corporation for follow-on work on the "Diffuser Augmented Wind Turbine" for $89.3K.

Hosted the "Wind Energy Innovative Systems Conference," May 22-25, 1979.

Received and submitted to TIC the final report for the FY78 funded effort by the University of Dayton Research Institute entitled "Electrofluid Dynamic Generator Program".

Received the final report for the FY78 funded effort by the University of Dayton Research Institute entitled "An Analysis of the Madaras Rotor Power Plant".

Planned Activities

Complete contract negotiations for the Marks "Aerosol Generator" study.

Complete contract negotiations for three R&D studies responding to RFP RH-9-8085.

Review unsolicited Proposals.

Complete the proceedings for the WEIS conference.

Review draft final reports.

Output

Development of advanced wind systems that have the potential of being cost competitive with conventional systems

Technical reports on the innovative R&D studies

Technical and programmatic support of the Federal Wind Energy Program

Budget for FY79	Expenditures	Transfer from FY78
	$137K	Budget $160K
Initial $724K	Commitments	Expenditure $129K
Reprogrammed $754K	$158K	Commitments $131K

COST ESTIMATING AND ENGINEERING ANALYSIS OF INNOVATIVE WECS

Robert McConnell

Objective

Estimate the cost of energy produced by innovative WECS.

Accomplishments (April 1 - June 30, 1979)

Conducted reviews both internal and external, of the report entitled "A General Reliability and Safety Methodology and its Application to Wind Energy Conversion Systems".

Conducted Reviews, both internal and external, of the report entitled "Screening Methodology for Innovative Wind Systems" prepared by Science Applications, Inc.

Evaluated the McDonnell Douglas Giromill System using classic value indicators and presented results in a paper entitled "Giromill Overview" at the Wind Energy Innovative System Conference.

Planned Activities (July 1 - September 30, 1979)

Incorporate review comments into draft reports and produce final reports.

Prepare and submit for review a work statement for the development of a "Costing Methodology for Innovative Wind Systems in their Development Phase".

Outline the purpose and agenda for a "Wind Energy Cost Definition Workshop".

Output

Technical report describing a methodology for evaluating an innovative WECS' reliability and safety and its associated operation and maintenance costs.

Technical report describing a methodology for screening innovative WECS in their concept phase.

Technical report describing a methodology for estimating the impact of development costs on the life cycle costs of innovative WECS.

Budget for FY79	Expenditures
Initial $124K Reprogrammed $174K	$137.5K

UTILITY ANALYTICAL MODELING

David Percival

Objective

Establish the capability to represent wind-derived generation in electric utility generation planning models so that the economic value of the WECS option may be examined.

Approach

Procure established utility generation planning models.

Develop methodology for WECS representation and integrate it into the utility models.

Accomplishments

Utility Models:

Completed and submitted to DOE Draft Report on utility production cost model evaluations entitled "Electric utility WECS analytical modeling - production cost model evaluations".

Completed a draft paper entitled "Integration of Intermittent Resources into Baleriaux-Booth production cost models".

WECS Representations:

Received JBF and Stone and Webster models and successfully compiled and duplicated test case for the JBF model.

Tested SIMWEST.

Planned Activities

Commence training on PROMOD.

Complete final version of report on "Integration of Intermittent Resources into Baleriaux-Booth Production Cost Models" and submit to IEEE.

Compare wind models and incorporate selected wind model into value determination methodology.

Output

Report on utility production cost model evaluations.

Report on methodology and users manual for the WECS representation.

Utility planning models incorporating WECS such that DOE/SERI studies may be performed.

Budget	Expenditure
Initial $145K	$77K

ECONOMICS OF SWECS TIED TO THE UTILITY GRID

MICHAEL EDESESS

PR-356
AUGUST 21, 1979

OBJECTIVE

INVESTIGATE THE ECONOMICS OF USER-OWNED, ON-SITE WECS WITH UTILITY BACK-UP.

ACCOMPLISHMENTS

DEVELOPED AN APPROACH TO THE PROBLEM OF EVALUATING THE ECONOMICS OF USER-OWNED WECS WHICH RECOGNIZES THE RELATIVE FINANCIAL RISK OF USER-OWNED WECS WITH UTILITY BACK-UP VERSUS TOTAL DEPENDENCE ON UTILITY FOR POWER.

PLANNED ACTIVITIES

CONSTRUCT ALGORITHM FOR ASSESSING THE VALUE OF ON-SITE WECS, CONSIDERING UTILITY BACK-UP AND BUY-BACK RATES, WIND REGIME, LOAD PROFILE AND RELATIVE WECS FINANCIAL RISK COMPARED WITH RISK OF TOTAL DEPENDENCE ON UTILITY FOR POWER.

OUTPUT

DRAFT REPORT AT END OF FY79.

BUDGET	EXPENDITURE
INITIAL $195K	$66K
REPROGRAMMED $120K	

Products Liability Issues Associated with SWECS

Robert Noun

Objective

Provide policy alternatives to assure that products liability issues associated with SWECS do not impede the increased use of such systems.

Accomplishments

Consultant hired to provide comment and product failure analysis.

Completed paper identifying legal issues and submitted it for review.

Planned Activities

Initiate the development and analysis of policy alternatives.

Complete report summarizing legal issues and providing a set of policy alternatives.

Output

Report summarizing legal issues, possible alternatives for addressing these issues, and an integrated set of policy alternatives. The policy alternatives will be useful to DOE, wind systems industry, and others involved in wind energy.

Budget	Expenditure
Initial $67K Reprogrammed $52K	$15K

ENVIRONMENTAL IMPACT ASSESSMENT OF SMALL WIND ENERGY CONVERSION SYSTEMS

Kathryn Lawrence

Objective

Identify and analyze the life-cycle environmental impacts associated with deploying small (less than 100 kW) utility connected and non-utility connected WECS.

Accomplishments

University of Michigan, Radiation Laboratory, completed subcontract obligations in June by providing SERI and DOE/WSB with a 15-minute videocassette on potential TV interference by the Block Island wind turbine.

Previous WECS environmental research summarized and evaluated; the literature synthesis will be presented in the Progress Report, Mid-September 1979.

Prepared survey on the aesthetics of SWECS; survey was submitted to SERI's Survey Review Committee for approval.

Planned Activities

Contact selected SWECS manufacturers to determine if environmental barriers have been encountered.

Quantitatively determine materials requirements and environmental emissions of SWECS manufacture, installation, operation, and decommission.

Assess health and ecological implications of emissions.

Output

A 15 minute color videocassette presenting potential TV interference by the Block Island WTG.

Progress Report presenting a synthesis and evaluation of previous WECS environmental research; SERI's survey on the aesthetics of SWECS; a description of generic SWECS designs for which environmental analyses will be performed; and an outline of planned task activities.

Final report which presents an analysis of the potential health and ecological effects of SWECS for each life-cycle phase (system fabrication through decommission) and an evaluation of the current status of environmental effects research and recommendation of additional research needs.

Final report which presents the results of the aesthetics survey of SWECS.

Budget	Expenditures
Initial $143K Reprogrammed $123K	$49.5K

Planning

Objectives

Develop plans and coordinate the efforts of SERI Wind Energy Systems Program.

Provide SERI support of the Federal Wind Energy Program.

Accomplishments

Completed the SERI institutional five-year plan

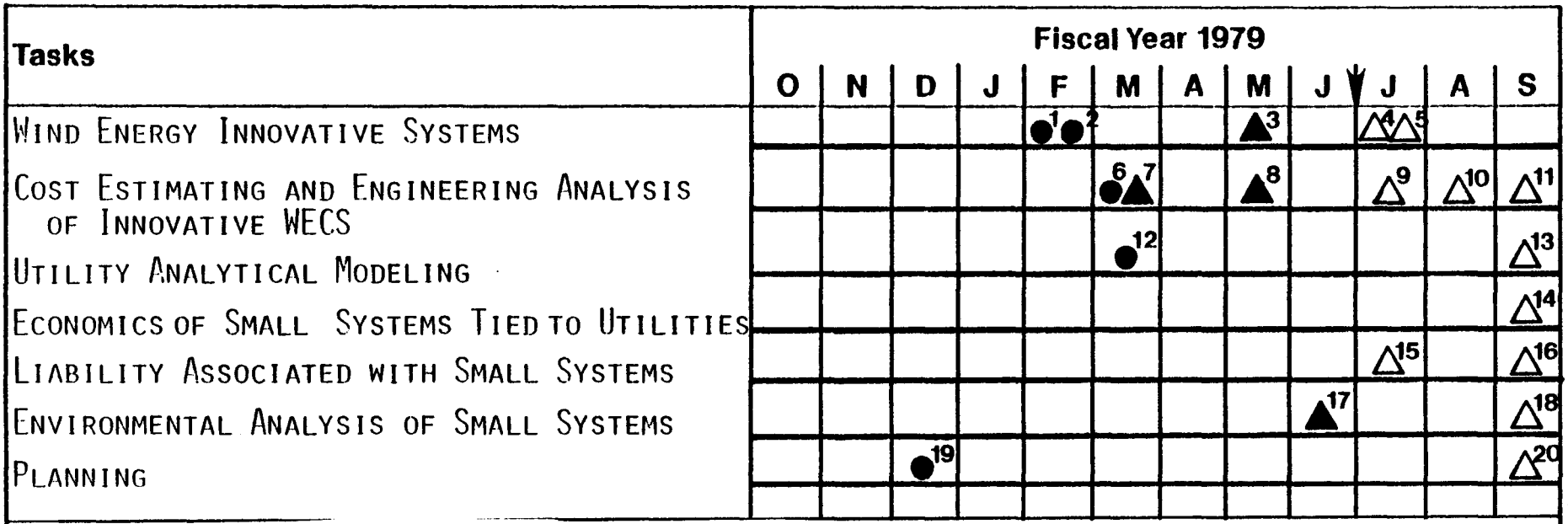
Completed the draft FY80 annual operating plan

Presented the 2nd quarterly review to WSB.

Supported WSB in planning and budget exercises.

Submitted schedule 189 No. 320-79 for "Wind Systems Studies" to SERI and DOE for approval.

WIND — MILESTONES



1. Award of generic study contracts
2. RFP released on R&D studies
3. WEIS Conference
4. Completion of generic studies
5. Award of new R&D studies
6. Survey completed of cost studies
7. Draft report of reliability
8. Draft report of screening methodology
9. Final report of reliability and maintenance cost study
10. Final report of screening methodology
11. Draft work statement on cost methodology for development phase of innovative concepts
12. Survey completed
13. Model operational
14. Draft report on the evaluation of on-site wind power
15. Critical issues defined
16. Analysis completed
17. TV interference film completed
18. Draft interim report on environmental effects of the production of WECS
19. Draft program development plan completed
20. Draft program development plan

Legend:

- ○ Start or Scheduled Intermediate Event
- ● Completed Intermediate Event
- △ Scheduled Milestone
- ▲ Completed Milestone

Planned Activities

Complete SERI Annual Operating Plan (AOP) for FY80.

Develop task plans for FY80 and FY81 for WSB.

Complete draft program development plan for wind activities.

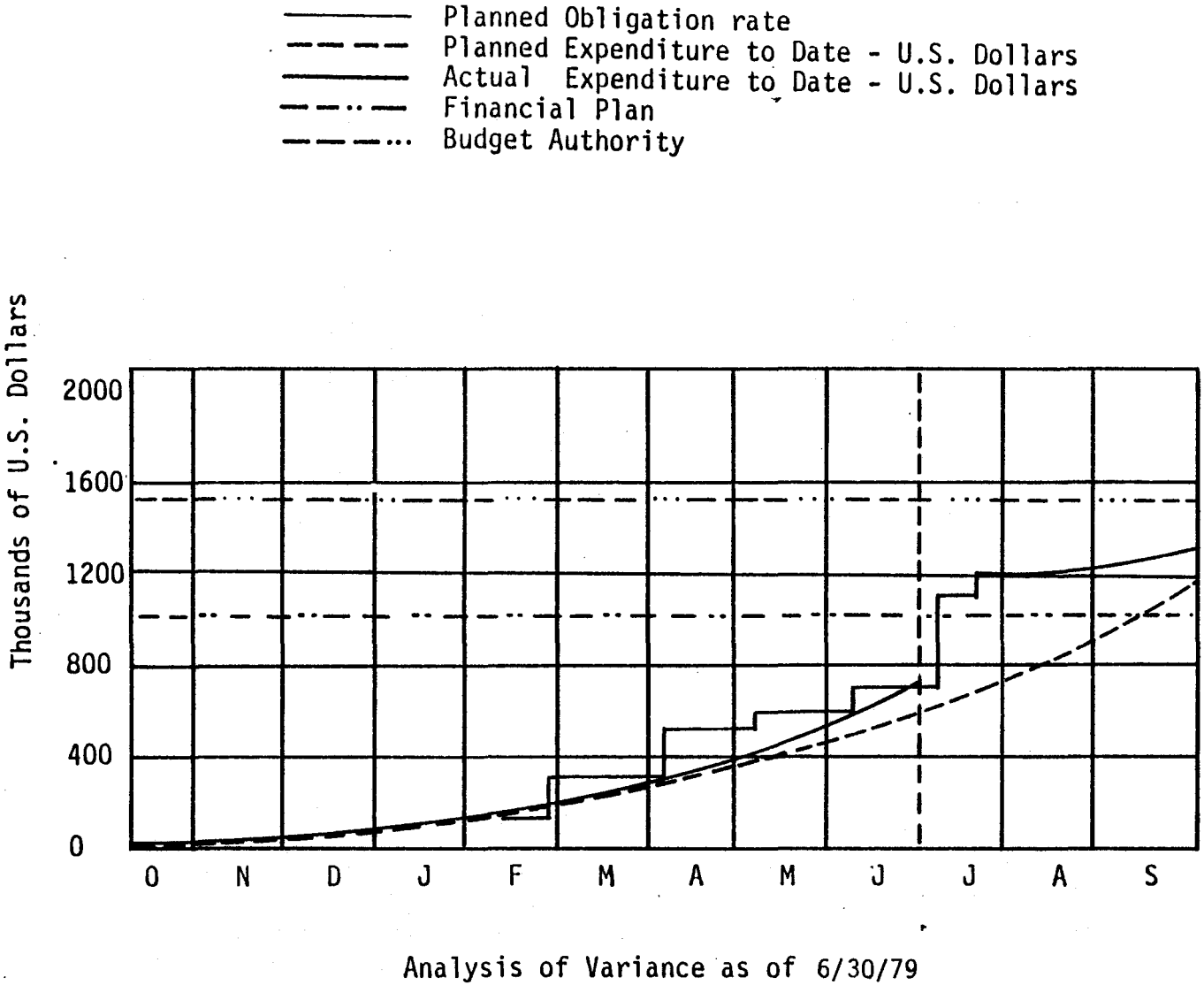
Budget	Expenditure
Initial $32K Reprogrammed $62K	$50.7K

Wind Energy Systems (WES) Program Funding

Task	Lead Branch	Subcontracts	Total
Wind Energy Innovative Systems Program	Special Programs	631	754
Cost Estimating & Engineering Analysis	Systems Analysis	10	174
Utility Analytical Modeling	Systems Analysis	45	145
Economics of Small Systems Tied to Utilities	Systems Analysis	0	120
Liability Associated with Small Systems	Institutional & Environmental Assess.	0	52
Environmental Analysis of Small Systems	Institutional & Environmental Assess.	0	123
Planning & Administration	Systems Analysis	0	62
Wind Resources Analysis[A]	Energy Resource	45	140
Technical Information[B] Dissemination	Communications	186	303

A Basic and Applied Research (Program Area 14)
B Commercialization Activities (Program Area 18)

WIND ENERGY SYSTEMS



Analysis of Variance as of 6/30/79

PR-356
August 21, 1979

WIND ENERGY INNOVATIVE SYSTEMS

Irwin E. Vas

Objective

Determine technical and economic feasibility of Innovative Wind Energy Systems.

Approach

Monitor, review, and assess on-going R&D projects.

Conduct site visits and project reviews.

Support generic studies by subcontracts.

Conduct a programmatic workshop.

Review and assess unsolicited proposals.

Support specific R&D solicited innovative studies.

PRINCIPAL SUBCONTRACTORS FOR FY79 R&D PROJECTS

Project Title	Subcontractor	Project Code	Contract No.	Principal Investigator
Innovative Wind Turbine	West Virginia University	WVU	EY-76-C-05-5135	Richard E. Walters
Diffuser Augmented Wind Turbines (DAWT)	Grumman Aerospace	G-D	XH-9-8073-1	Ken Foreman
Tornado-Type Wind Energy Systems Phase II (Tornado)	Grumman Aerospace	G-T	EX-76-C-01-2555	James T. Yen
Tests and Devices for Wind/ Electric Power Charged Aerosol Generators (EFD)	Marks Polarized	MP	EG-77-C-01-2774	Alvin M. Marks
Electrofluid Dynamic Wind Generator Program (EFD)	University of Dayton	UDE	XH-9-8074-1	John E. Minardi
Energy from Humid Air (Humid Air)	South Dakota School of Mines and Technology	SD	DE-AC01-79ET23052	Thomas K. Oliver
The Madaras Rotor Power Plant Phase I (Madaras)	University of Dayton Research Institute	UDM	EX-76-S-01-2554	Dale H. Whitford
Vortex Augmentors for Wind Energy Conversion (Vortex)	Polytechnic Institute of New York	PINY	E(49-18)2358	Pasquale M. Sforza

Innovative Wind Turbines

West Virginia University
EY-76-C-05-5153
(Richard E. Walters, P.I.)

Objective

Investigate the technical and economic feasibility of a vertical axis wind turbine having straight blades constructed with circulation control airfoil sections.

Approach

Design and construct a revised VAWT test model and associated instrumentation.

Conduct indoor test to assess lift, drag, and moment characteristics.

Predict performance of circulation controlled VAWT in a wind situation.

Estimate economic viability of system as compared to conventional systems.

Tasks

	Task Number
Circulation control blade theory with viscous effects	1.1
Tare airfoil computer codes	1.2
Circulation control blade and flip tests	1.3
Design study, sensor location study, and hardware preparation	1.4
Large blade tests	1.5
System/cost study (Alleghany Ballistics Lab)	1.6
Blade and instrument design	1.7
Blade and instrumentation procurement and fabrication	1.8
Indoor tests	1.9

Accomplishments

Fabrication completed on the circulation controlled blades.

Completed the aerodynamic tare measurements for the Rotating Support arms.

Indoor testing continued on the conventional blade measuring blade lift, drag, and pitching moment.

Presented a technical paper at the WEIS Conference, May 1979.

Submitted the draft final report Vol III for tasks 1.1 thru 1.6.

Planned Activities

Complete indoor tests.

Complete review of the draft final for tasks 1.1 to 1.6 (SERI).

Assessment

No problems on current work are foreseen at this time.

Project will probably not be completed by August 15, 1979.

Diffuser Augmented Wind Turbine

Grumman Aerospace Corporation
XH-9-8073-1
(Ken Foreman P.I.)

Objective

Develop and refine the engineering design of diffuser augmented wind turbines (DAWT) for small and intermediate sized machines.

Approach

Determine cost and power estimates for candidate DAWT systems when constructed of three separate materials.

Determine size, cost, manufacturing, and installation approaches for each candidate DAWT system.

Tasks

	Task Numbers
Wind Tunnel and Small Scale Tests	2.1
Field Test Plan	2.2
Windstream 18 Diffuser, Turntable, Instrument Design	2.3
Performance Calculation	2.4
Economic Analysis	2.5
Size and Power Rating	2.6
Design studies for three materials of construction	2.7
Manufacturing and installation approaches	2.8
Cost and Power estimate	2.9
Prototype sizing and costing	2.10

Accomplishments

Presented a paper at the WEIS Conference, May 1979.

Size and Power rating studies have been initiated for three DAWT systems.

Design studies of DAWT systems constructed of Ferrocement have been initiated.

Planned Activities

Complete the final report for FY78 funded effort.

Continue size and power rating studies.

Initiate design studies of DAWT systems constructed of fiberglass.

Assessment

The FY78 funded effort has been completed and comments on the draft final report has been submitted to the principal investigator.

The FY79 funded effort has been initiated and is on schedule.

Tornado Type Wind Energy Systems

Grumman Aerospace Corporation
EX-76-C0-01-2555
(James T. Yen P.I.)

Objective

Determine technical and economic feasibility of the tornado type machine.

Approach

Complete theoretical analyses utilizing models to predict optimum configurations and performance of full-scale systems.

Conduct wind tunnel tests of small models and compare the performance characteristics with predicted values.

Estimate the augmentation factor for the system using measured results.

Design, construct, and test mid-scale spiral and vaned type models.

Tasks

	Task Numbers
Flow field analysis of vortex systems	3.1
Three-foot model test	3.2
Ten-foot spiral design and fabrication	3.3
One-foot turbine design and fabrication	3.4
Ten-foot diameter vaned model, design and fabrication	3.5
Tests of spiral and vaned models	3.6
Structural and cost analysis	3.7

Accomplishments

Completed realignment and calibration of load cell.

Completed rework of instrument package to eliminate extraneous effects on load cell readings.

Designed and initiated construction of three high speed wind tunnel models of 10 in., 15 in., and 20 in. diameter with a 4 in. diameter turbine.

Continued analysis of data collected in Task 3.2 and obtained an average C_p 0.10 based on tower frontal area.

Presented a paper at the WEIS Conference, May 1979.

Planned Activities

Complete construction of high speed models and test.

Complete the review of the final report of the FY77 funded effort. (SERI)

Complete the draft final report for the FY78 funded effort.

Assessment

The current effort is behind schedule due to lack of an available wind tunnel testing facility.

Test and Devices for Wind/Electric Power
Charged Aerosol Generator

Marks Polarized Corporation
EG-77-C-01-2774
(Alvin M. Marks, P.I.)

Objective

Experimentally evaluate four methods of producing charged droplets and compare the experimental results with available predictions.

Approach

Develop analytical methods to determine the performance of "charging" methods.

Design, construct, and test the charging methods over a range of conditions.

Evaluate the charging methods and compare the experimental results with the analytical predictions.

Tasks

	Task Numbers
Test of Array 1	4.1
Test of water jet/metal charging method	4.2
Test of electrojet charging method	4.3
Test of steam/metal charging method	4.4
Test of steam microjet condensation method	4.5

Accomplishments

Presented a paper at the WEIS Conference, May 1979.

The draft final report for tasks 4.1 to 4.5 was submitted for review.

Planned Activities

Complete and submit for review a draft final report on Tasks 4.1 to 4.5.

Assessment

The current efforts have not all been completed as planned.

A renewal proposal has been submitted by Marks Polarized Corporation at a funding level of $65K with award anticipated during the next quarter.

Electrofluid Dynamic Wind Driven Generator

University of Dayton Research Institute
XH-9-8074-1
(John E. Minardi, P.I.)

Objective

Provide a sufficient density of charged water droplets of low-mobility to experimentally evaluate EFD generator geometries.

Develop techniques for providing low-mobility charged water droplets for wind energy applications in a cost effective manner.

Approach

Develop theoretical models to provide limiting conditions for droplet and generator performance.

Conduct wind tunnel studies, develop charge droplet production methods, and compare results with analyses.

Tasks

	Task Numbers
Laboratory Colloid Generating Experiment	5.1
Experimental Configuration	5.2
Colloid Generation Experiments	5.3
EFD Generator Performance	5.4
Critical Problem Areas phase I	5.5
Theoretical Studies of Economic Current Production and generator geometry	5.6
Energy Economic Charge Production Experiments	5.7
Generator Performance Experiments	5.8
Critical Problem Areas phase II	5.9

Accomplishments

The final report for the FY78 funded project was received and submitted to TIC for distribution.

Completed a review of the literature on the production of bubbles and submicron droplets.

Conducted studies to determine the effects of water distribution requirements on generator geometry.

Completed design and initiated fabrication of a single large electrode geometry.

Initiated the design of a small bubble generator.

Presented a paper at the WEIS Conference, May 1979.

PLANNED ACTIVITIES

CONTINUE THEORETICAL STUDIES OF CURRENT PRODUCTION AND GENERATOR GEOMETRY.

CONDUCT TESTS OF ECONOMIC CHARGE PRODUCTION AND GENERATOR GEOMETRIES.

ASSESSMENT

THE CURRENT EFFORTS ARE ON SCHEDULE.

Energy from Humid Air

South Dakota School of Mines and Technology
DE-AC01-79ET23052
(Thomas K. Oliver)

Objective

Determine a cost effective method of converting the latent heat of water vapor in humid air into mechanical work.

Approach

Determine the potential of the expansion-compression technique for removing energy from humid air.

Tasks

	Task Numbers
Develop methods to evaluate tower flow losses, condensation, and compression	6.1
Investigate cooling methods based on available meteorological data	6.2
Perform parametric studies for task 6.1	6.3
Develop economic analysis	6.4
Computer modeling of the flow	6.5
Study of losses	6.6
Condensation & cooling dynamics	6.7
System performance	6.8
Structural design	6.9
Economic Estimates	6.10

Accomplishments

Tasks 6.1 to 6.4 have been completed and comments on the draft final report submitted to the principal investigator.

Initiated the search of current literature and published data in the areas of rotating vortex and swirling flows.

Completed the initial computer model incorporating continuity and momentum equations and obtained a stable solution.

Presented a paper at the WEIS Conference, May 1979.

Planned Activities

Complete the final report on the FY78 funded effort.

An Analysis of the Madaras Rotor Power Plant

University of Dayton Research Institute
EX-76-S-01-2554
(Dale H. Whitford P.I.)

Objectives

Determine the cost effectiveness of the Madaras Rotor Power Plant in the 100 MW to 200 MW Range.

Approach

Conduct theoretical and experimental studies of rotating cylinders.

Evaluate the structural, electric, and mechanical components of the systems utilizing modern technology.

Perform an economic evaluation and performance simulation of the system for various plant sizes.

Tasks

	Task Numbers
Vortex Analysis of Madaras Rotor	7.1
Model Design, Fabrication, and Tests	7.2
Data Evaluation	7.3
Electrical/Mechanical Studies	7.4
Performance Analysis	7.5
Conduct Economic Studies	7.6

Accomplishments

All tasks have been satisfactorily completed.

The final report has been submitted by the principal investigator.

Planned Activities

No additional studies currently considered in this area.

Vortex Augmentors for Wind Energy Conversion

Polytechnic Institute of New York
ET-77-C-01-2358
(Pasquale M. Sforza)

Objective

Determine the technical feasibility, performance, and economic potential of the Delta Wing Type Vortex Augmentor concept.

Approach

Adequately instrument the prototype Delta Wind Vortex Augmentor.

Determine stability and control safety aspects of the system under operating conditions.

Develop performance characteristics of the prototype system.

Tasks

	Task Numbers
Field Test Program	8.1
Test and Analysis	8.2
Wind Tunnel Tests	8.3
Economic Studies	8.4

ACCOMPLISHMENTS

SENSOR DEPLOYMENT ALTERED AND COMPUTER SOFTWARE ALTERED TO ACCOUNT FOR RELOCATION.

CONTINUED FIELD TESTING, STABILITY AND CONTROL CHARACTERISTICS REMAIN STABLE.

PERFORMANCE MAPPING BEING CARRIED OUT ROUTINELY.

Planned Activities

Complete field tests and evaluate the Vortex Augmentor Concept (VAC) prototype.

Complete field tests and evaluate the VAC with flap addition.

Assess and optimize flap position using wind tunnel tests.

Develop the economic model for the VAC.

Assessment

The project is behind schedule due to previous weather delays and a no cost extension has been requested to August 31, 1979.

Principal Subcontracts for FY79 Generic Studies

A Definitive Generic Study of Augmented Horizontal Axis WES (HAWT)	Aerovironment, Inc.	AH	AH-9-8003-1	Peter Lissaman
A Definitive Generic Study of High Lift Device WES (High Lift)	Aerovironment, Inc.	AHL	AH-9-8003-2	Peter Lissaman
A Definitive Generic Study of Augmented Horizontal Axis WES (HAWT)	Tetra-Tech, Inc.	TT	AH-9-8003-3	Mark Harper
A Definitive Generic Study of Augmented Vertical Axis WES (VAWT)	New York University	NYU	AH-9-8003-4	Martin Hoffert
A Definitive Generic Study of Sail Wing WES (Sail Wing)	Washington University Technical Associates	WU	AH-9-8003-5	K. H. Hohenemser
A Definitive Generic Study of Vortex Extraction WES (Vortex)	JBF Scientific Corp.	JBF	AH-9-8004-6	Theodore R. Kornreich

"A Definitive Generic Study of Augmented Horizontal-Axis Wind Energy Systems"

Aerovironment, Inc.
(AII-9-8003-1)

Peter Lissaman

Objective

Provide a critical evaluation of the potential cost-effectiveness of Augmented Horizontal-Axis Wind Energy Systems.

Approach

The study will address the following topics for each wind energy system:

Cost-effectiveness ($/kWh)
Advantages and disadvantages of concept
Capacity factors
Potential areas for improvement
Direction for future efforts, if any
Bibliography--the listing provided above is to be used as a guide. Documentation of additional critical facets for the study may be included.

Tasks

	Task Numbers
Perform a critical technical review of the generic group Augmented Horizontal Axis Wind Energy Systems	9.1
Compare the various types of Augmented Horizontal-Axis Wind Energy Systems with unaugmented conventional Wind Energy Systems	9.2

Accomplishments

Completed all technical tasks and submitted a draft final report for review.

A paper was presented at the WEIS Conference, May 1979.

Planned Activities

The final report is to be completed when review comments have been received.

Assessment

The draft final report is to be reviewed by August 1979. (SERI)

A no cost extension has been requested to allow for the incorporation of comments into the final report.

"A Definitive Generic Study of High Lift Device Wind Energy Systems"

Aerovironment
(AH-9-8003-2)

Peter Lissaman

Objective

Provide a critical evaluation of the potential cost-effectiveness of High Lift Device Wind Energy Systems.

Approach

The study will address the following topics for each wind energy system:

- Cost-effectiveness ($/kWh)
- Advantages and disadvantages of concept
- Capacity factors
- Potential areas for improvement
- Direction for future efforts, if any
- Bibliography--the listing provided above is to be used as a guide. Documentation of additional critical facets for the study may be included.

Tasks

	Task Numbers
Perform a critical technical review of the generic group High Lift Wind Energy Systems	10.1
Compare the various types of High Lift Wind Energy Systems with unaugmented conventional Wind Energy Systems	10.2

Accomplishments

All technical tasks have been completed and a draft final report submitted.

A paper was presented at the WEIS Conference, May 1979.

Planned Activities

The final report is to be completed when review comments have been received.

Assessment

The draft final report is to be reviewed by August 1979. (SERI).

A no cost extension has been requested to allow for comments to be incorporated into the final report.

"A Definitive Generic Study of Augmented Horizontal-Axis Wind Energy Systems"

Tetra-Tech, Inc.
(AH-9-8003-3)

Mark Harper

Objectives

Provide a critical evaluation of the potential cost-effectiveness of Augmented Horizontal-Axis Wind Energy Systems.

Approach

The study will address the following topics for each wind energy system:

- Cost-effectiveness ($/kWh)
- Advantages and disadvantages of concept
- Capacity factors
- Potential areas for improvement
- Direction for future efforts, if any
- Bibliography--the listing provided above is to be used as a guide. Documentation of additional critical facets for the study may be included.

Tasks

	Task Numbers
Perform a critical technical review of the generic group Augmented Horizontal-Axis Wind Energy Systems	11.1
Compare the various types of Augmented Horizontal-Axis Wind Energy Systems with unaugmented conventional Wind Energy Systems	11.2

Accomplishments

All technical tasks have been completed and a draft final report submitted.

A paper was presented at the WEIS Conference, May 1979.

Planned Activities

THE FINAL REPORT IS TO BE COMPLETED WHEN REVIEW COMMENTS HAVE BEEN RECEIVED.

Assessment

THE DRAFT FINAL REPORT IS TO BE REVIEWED BY AUGUST 1979. (SERI)

A NO COST EXTENSION HAS BEEN REQUESTED TO ALLOW FOR THE INCORPORATION OF COMMENTS INTO THE FINAL REPORT.

"A Definitive Generic Study of Augmented Vertical-Axis Wind Energy Systems"

New York University
(AH-9-8003-4)

Martin I. Hoffert

Objective

Provide a critical evaluation of the potential cost-effectiveness of Augmented Vertical-Axis Wind Energy Systems.

Approach

The study will address the following topics for each wind energy system:

- Cost-effectiveness ($/kWh)
- Advantages and disadvantages of concept
- Capacity factors
- Potential areas for improvement
- Direction for future efforts, if any
- Bibliography--the listing provided above is to be used as a guide. Documentation of additional critical facets for the study may be included.

Tasks

	Task Numbers
Perform a critical technical review of the generic group Augmented Vertical-Axis Wind Energy Systems	12.1
Compare the various types of Augmented Vertical-Axis Wind Energy Systems with unaugmented conventional Wind Energy Systems	12.2

Accomplishments

Technical tasks have been completed and a draft final report submitted.

A paper was presented at the WEIS Conference, May 1979.

Planned Activities

The final report is to be completed during September 1979.

Assessment

The draft final report is to be reviewed during July 1979. (SERI)

A no cost extension has been requested to allow comments to be incorporated into the final report.

"A Definitive Generic Study of Sail Wing Wind Energy Systems"

Washington University Technical Assoc., Inc.
(AII-9-8003-5)

Dr. K. H. Hohenemser

Objective

Provide a critical evaluation of the potential cost-effectiveness of Sail Wing Wind Energy Systems.

Approach

The study will address the following topics for each wind energy system:

- Cost-effectiveness ($/kWh)
- Advantages and disadvantages of concept
- Capacity factors
- Potential areas for improvement
- Direction for future efforts if any
- Bibliography--the listing provided above is to be used as a guide. Documentation of additional critical facets for the study may be included.

Tasks

	Task Numbers
Perform a critical technical review of the generic group Sail Wing Wind Energy Systems	13.1
Compare the various types of Sail Wing Wind Energy Systems with unaugmented conventional Wind Energy Systems	13.2

Accomplishments

All technical tasks have been completed and a draft final report submitted.

A paper was presented at the WEIS Conference, May 1979.

Planned Activities

The final report is to be completed when review comments have been received.

Assessment

The draft final report is to be reviewed by August 1979. (SERI)

"A Definitive Generic Study of Vortex Extraction Wind Energy Systems"

JBF Scientific, Inc.
(AH-9-8003-6)

Theodore R. Kornreich

Objective

Provide a critical evaluation of the potential cost-effectiveness of Vortex Extraction Wind Energy Systems.

Approach

The study will address the following topics for each wind energy system:

Cost-effectiveness ($/kWh)
Advantages and disadvantages of concept
Capacity factors
Potential areas for improvement
Direction for future efforts, if any
Bibliography--the listing provided above is to be used as a guide. Documentation of additional critical facets for the study may be included.

Tasks

	Task Numbers
Perform a critical technical review of the generic group Vortex Extraction Wind Energy Systems	14.1
Compare the various types of Vortex Extraction Wind Energy Systems with unaugmented conventional Wind Energy Systems	14.2

Accomplishments

All technical tasks have been completed and a draft final report submitted.

A paper was presented at the WEIS Conference, May 1979.

Planned Activities

The final report is to be completed when review comments have been received.

Assessment

The draft final report is to be reviewed by August 1979.

A no cost extension has been requested to allow for comments to be incorporated into the final report.

Program Management

Accomplishments

Reviewed current R&D projects on a continuing basis--details provided previously.

Technical evaluation and rank ordering was completed by a SERI panel and members of the Advisory Committee (or their representatives) for the proposals which were submitted in response to the RFP, R4-9-8085, entitled "Advanced and Innovative Wind Energy Concept Development".

Hosted the WEIS Conference May 23-25 in Colorado Springs, Colorado. This effort was coordinated with Rick Kottler, JBF, and the SERI Conference Group.

Completed technical reviews of three unsolicited proposals.

Planned Activities

Continue and complete activities relating to current R&D studies as indicated previously.

Complete award of the Marks "Aerosol Generator" follow-on contract.

Review unsolicited proposals.

Complete the proceedings of the WEIS Conference.

Support the planning of the SERI Wind Energy Systems Program.

Output

Develop and confirm by adequate tests specific innovative concepts that have the potential of being cost effective as compared to conventional systems.

Continue to develop a program plan for FY80 incorporating input provided at the WEIS Conference and supplemented by recommendations of the Advisory Committee.

Provide support to WSB in the programmatic activities.

R&D Subcontracted Projects, FY78 and 79

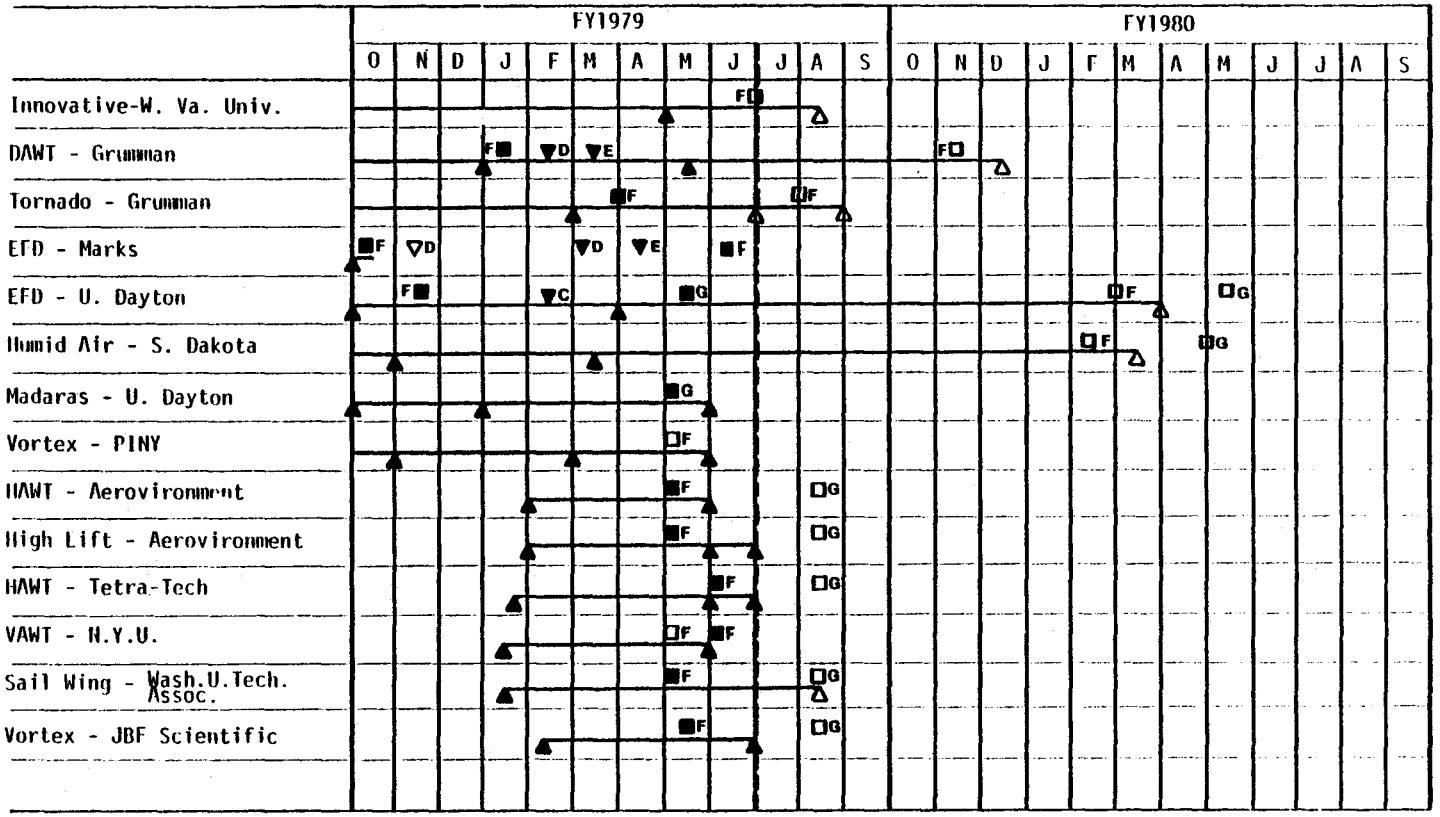
Title/Subcontractor	Termination Date Proposed Termination Date)	Funding Status			Projected Funding FY80
		Funding FY78	Additional Funding Requested FY79		
Inn. - W. VA. Univ.	August 15, 1979	99,888	0	100,000	
DAWT - Grumman	December 15, 1979	201,964	89,293		102,000
Tornado - Grumman	August 30, 1979	256,115	N/A	200,000	
EFD - Marks	April 30, 1980	99,448	64,007		N/A
EFD - U. Dayton	March 31, 1980	102,264	117,523		110,000
Hum. Air - S. Dakota	March 12, 1980	99,547	68,975		N/A
Madaras - U. Dayton	May 31, 1979	$143,171	0		0
Vortex - Piny	August 31, 1979	43,924	N/A	N/A	

Generic Subcontracted Projects FY79

Title/Subcontractor	Termination Date	Funding Status Funding FY79
HAWT - Aerovironment	May 31, 1979	21,827
High Lift - Aerovironment	June 30, 1979	22,772
HAWT - Tetra-Tech	June 30, 1979	24,677
VAWT - N.Y.U.	May 31, 1979	24,951
Sail Wing - W.U.T.A.	August 15, 1979	22,500
Vortex - JBF Scientific	June 30, 1979	24,950

CONTRACT NO. EG-77-C-01-4042 PRINCIPAL INVESTIGATOR Irwin E. Vas

CONTRACTOR SPO/SERI TITLE Wind Energy Innovative Systems PHONE NO. (303) 231-1935



A Contract Review, Site Visit

B Semi-Annual Report

C Proposal Submission

D Proposal Resubmission

E Procurement Initiation

F Draft Final Report

G Final Report

EXPLANATION

▽ Intermediate Event

△ Milestone

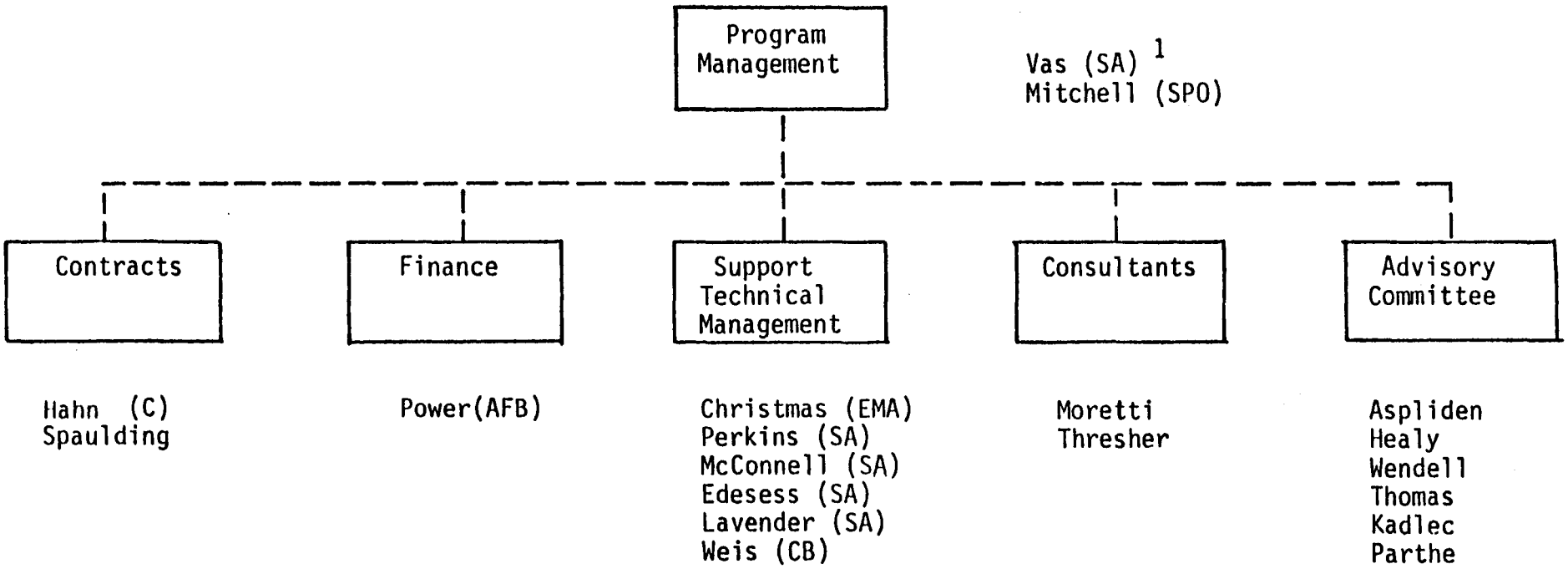
□ Report

Delivered - Filled Symbol

Planned - Open Symbol

MAJOR MILESTONE CHART FOR WEIS PROJECTS IN FY79 AND FY80.

WEIS PROGRAM MANAGEMENT CHART



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[1] Office/Branch abbreviations are defined below:

SPO Special Programs Office
C Contracts
AFB Accounting, Finance, and Budget
EMA Economics and Market Analysis
ERA Energy Resource Assessment
SA Systems Analysis
CB Communications Branch

PR-356
August 21, 1979

COST ESTIMATING AND ENGINEERING ANALYSIS OF INNOVATIVE WECS

Robert McConnell

Objective

Estimate the cost of energy produced by innovative WECS.

Accomplishments

Conducted reviews, both internal and external, of the report entitled "A General Reliability and Safety Methodology and its Application to Wind Energy Conversion Systems".

Conducted reviews, both internal and external, of the report entitled "Screening Methodology for Innovative Wind Systems" prepared by Science Applications, Inc.

Evaluated the McDonnell Douglas Giromill System using classic value indicators and presented results in a presentation entitled "Giromill Overview" at the Wind Energy Innovative System Conference.

Planned Activities

Incorporate review comments into draft reports and produce final reports.

Prepare and submit for review a work statement for the development of a "Costing Methodology for Innovative Wind Systems in their Development Phase".

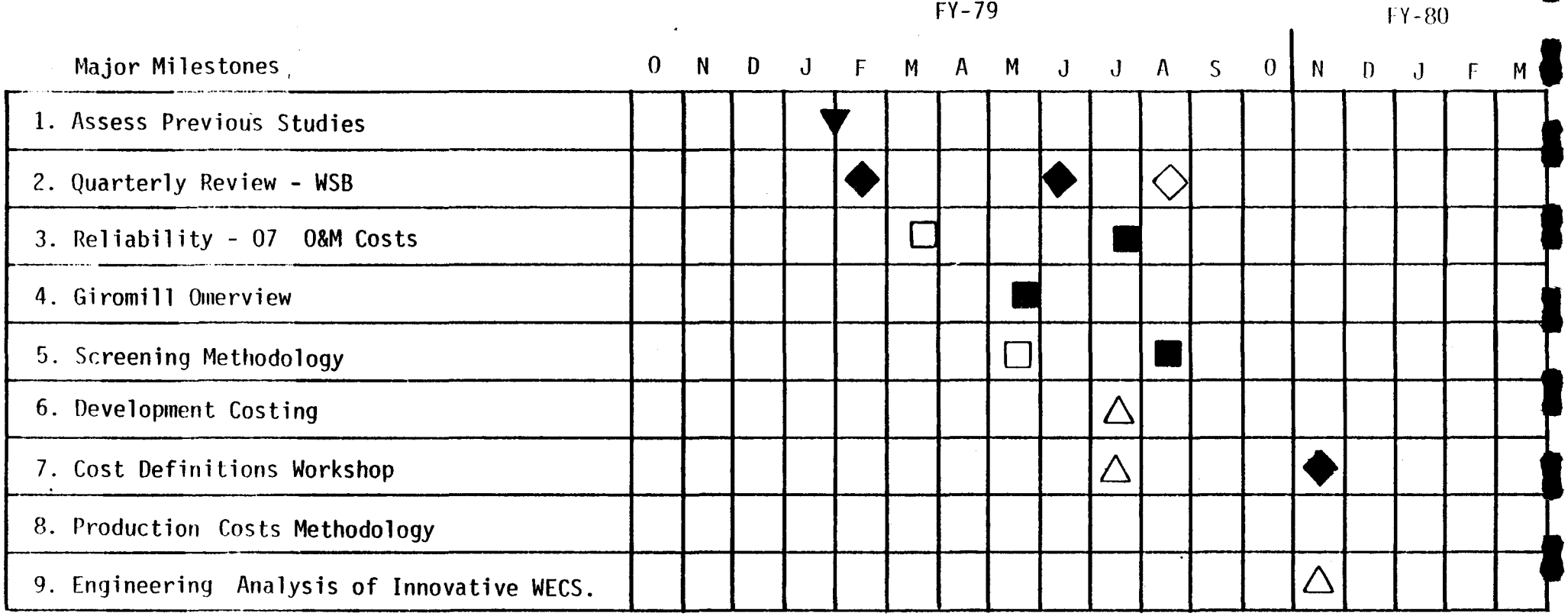
Outline the purpose and agenda for a "Wind Energy Cost Definition Workshop".

Output

Technical report describing a methodology for evaluating an innovative WECS' reliability and safety and its associated operation and maintenance costs.

Technical report describing a methodology for screening innovative WECS in their concept phase.

Technical report describing a methodlogy for estimating the impact of development costs on the life cycle costs of innovative WECS.



△ Begin Milestone

▼ Milestone Complete

◆ Workshop or Special Meeting

□ Draft Final Report

■ Final Report

Abstract and Reviewer Comments

A General Reliability and Safety Methodology and its Application to Wind Energy Conversion Systems.

Abstract

In conventional system reliability calculations, each component may be in the Operable state or the Repair state. These calculations derive system unavailability, or the probability of the system's being down for repairs. By introducing a third component state between Operable and Under Repair--namely, Defective But Defect Undetected--the methods developed in this article enable system safety projections to be made in addition to reliability projections. Also provided is a mechanism for computing the effect of inspection schedules on both safety and reliability. A Reliability and Safety Program (RASP) is detailed that performs these computations and also calculates costs for system inspections and repairs. RASP is applied to a simplified wind energy conversion system example.

Reviewer Comments (selected quotes)

Peter Moretti: I found this report very interesting. Its strength lies in the distinction between detected and undetected defects, which allows the construction of much more realistic fault trees. I think this will be important in safety analysis.

D. H. Reilly, Jr.
Deputy Director
Reliability and
Quality Assurance
NASA-Lewis

The report appears to develop a useful additional tool to determine the safety and reliability of a given system. The technique developed is based on existing general reliability methodology, but has extended these methods and developed unique software applicable to the analysis technique.

Dick Braasch: A major problem is a realistic determination of the quantitative data necessary to use the model. For example, what is the expected time for a defect to develop in the blade root attachment?

The modeling allows evaluation of improvement/reduction in failure rate or catastrophic failure obtained by increasing the instrumentation or other mechanistic devices on the machine.

I believe the high value from this work can be obtained by pursuing...The benefits of safety instrumentation.... .

T. J. Healy:
(Mr. Bollmeier) The report appears to be concerned only with reliability and safety with respect to wind machine or WECS design. I think other performance assurance disciplines (such as availability, maintainability, configuration management, quality assurance, and value engineering) should be included in the methodology. A more appropriate title would then be "A General Performance Assurance Methodology and Its Application to WECS."

The report does not mention how failure rates are to be measured and/or estimated. From our experience, data may not be available and it may be hard to come up with reasonable estimates. I recommend that procedures or guidelines be established in the methodology for estimation of component failure rates.

T. J. Healy:
(Mr. Bollmeier)
cont.

The report references reliability efforts already conducted or in progress on wind systems. In addition to those mentioned (Page 3), I am aware of at least two other major efforts. Boeing has conducted an extensive availability analysis as part of their MOD-2 design effort. As part of the Small Wind Systems Program here at Rocky Flats, extensive reliability analyses are being conducted as an integral part of the three 1-2kW High Reliability Wind Machine Development Programs and FMEA's are being performed on one of the 40kW programs.

Reviewer Comments on Screening Methodology

Emil Kadlec:

The effort and results seem worthwhile and useful for the intended purpose. This methodology should serve you well in your preliminary review of "innovative" proposals.

Bob Thresher:

I like the idea and the general approach.. Please keep me up on what's developing. I think the basic methodology will be useful beyond a screening for innovative systems.

I feel that the energy capture estimate is the most important variable in the COE equation. The next most important items are the weights of various components, but I think that it makes more sense to look first at the design criteria used for the preliminary design, then the weights themselves.

I would remove all of the appendix A data base. It will in general be used for questionable purposes. It also suffers from the effect of multiple configurations (i.e., teetering hub, fixed hub) and widely differing design criteria. I strongly object to the trend lines because of the difference in design criteria and configurants.

Peter Moretti: I read this report with great interest: the development of systematic comparisons of innovative devices is an important goal. The authors of the definitive generic studies have shown what can be achieved by systematic evaluation -- the same approaches should be applicable to new concepts. SAI has gotten a good start on doing this, but they have fallen short in several respects:

The formula for capacity factor C_F (page 7) is not necessarily correct for an innovative system; it is based on a particular performance model for horizontal axis machines with pitch control. In this assumption and in several other instances this shows a lack of aerodynamic expertise: the test for credibility of the claimed coefficient of performance (pages 2 and 7) are inadequate, and the concept of the stream tube is used incorrectly in discussing the energy in the wind (page 21).

The rules of thumb do not address really unconventional systems, whose weight ratios will not follow accepted rules. This is evident in the discussion of the diffuser-augmented system (page 22). The kinds of systems being proposed include such things as drag-chutes on winches: how can you categorize these subsystems into the proposed scheme? Hence the rules will tend to bounce the innovative systems right back into the "experts'" laps! We need to emphasize rules of thumb other than the classic subsystem weight ratios.

Peter Moretti: The methodology does not meet the objective of giving the benefit of the doubt to the alternative system. This is evident in the DAWT example: the analysis can only be taken to reject this concept, even though there is still considerable uncertainty about possible cost reduction through alternative materials and construction.

Ken Foreman: Because of the potential varieties and degrees of change that innovation can take, it is fundamentally questionable that an "universal" evaluation method can be devised.

It should be evident from these general comments that in our opinion, the methodology flow chart (Fig. 1) beyond the basic physics test is inadequate to handle truly innovative concepts. In our opinion, the latter procedural steps outlined, and used for the example, is insensitive to the commonly appreciated environment accompanying creative ideas and appears to treat innovation in the same manner as state-of-the-art, short term, engineering projects where "yes" or "no" conclusions may be reached.

Methodology output categories (i.e., accept, reject, etc.) are unnecessarily restrictive and definitive. Evaluator should have ability to estimate probability that WEIS could become competitive and its impact on national energy picture. Rough cut at probability could take form of: A) very likely, B) likely, C) probably, D) possibly, E) unlikely, and F) very unlikely; suggested categories are subjective and require panel inputs to improve accuracy.

KEN FOREMAN: (CONTINUED)

RULES OF THUMB (ROT) ARE DEVELOPED FROM PAST EXPERIENCE ABOUT A CLASS OF ENGINEERING SYSTEMS OR DEVICES. TO EXTRAPOLATE ROT TO UNCONVENTIONAL INNOVATIVE SYSTEMS IS A MISUSE OF STATISTICS BEYOND RATIONALITY. THE DATA BASE PROPOSED TO BE USED, INCIDENTALLY, IS HEAVILY WEIGHTED BY PAPER DESIGN STUDY INPUTS. EXPERIENCE SHOWS THAT THESE PAPER STUDIES HAVE BEEN NOTORIOUSLY OPTIMISTIC IN THE LIGHT OF ACTUAL EXPERIENCE AND THE FINAL SCORE STILL IS NOT IN ON THE LONG TERM PERFORMANCE AND ECONOMICS OF EVEN CONVENTIONAL HAWT. THEREFORE, THE ROT APPROACH SHOULD NOT BE TAKEN TOO SERIOUSLY.

THE DAWT DATA USED FOR SAMPLE CALCULATIONS IS OUT-DATED. THE SCREENING PROCESS CAN BE MISUSED BY EVALUATIONS LACKING SENSITIVITY TO TECHNICAL PROGRESS, IMAGINATION, OR GUT-APPRECIATION OF INNOVATIVE CONCEPTS.

THE UNDUE CONCENTRATION ON A SPECIFIC CONFIGURATION LEADS TO LARGE ERRORS IN UNDERESTIMATING THE COMPLETE PICTURE. TOO MUCH EXPERTISE, CONCENTRATED NARROWLY ON A SMALL DISCIPLINE OR TECHNOLOGY, EXAGGERATES THE EFFECT ON THE BROADER FUNCTIONAL CAPABILITY OF THE WEIS CONCEPT. THE ONLY EXCUSE FOR SUCH SUPERFICIAL TREATMENT IS THAT SAI HAD A LOW BUDGET AND SHORT TIME TO PRODUCE THEIR WORK. THE DANGER IN ALLOWING THESE RESULTS TO REMAIN IN THE FINAL DOCUMENT IS THAT DECISION MAKERS WHO ARE NOT AWARE OF THE INADEQUACY OF THE ANALYSIS MAY BE MISLEAD.

Reviewer Comments

Giromill Overview

Roger Moment: Basically, the report is clearly written and provides a good summary of the development of the Giromill concept. The rules-of-thumb that you have described are an interesting means of providing a quick comparison of newly developed wind systems. However, we would like to reinforce the caution that you have expressed, i.e., that cost and performance estimates are often based on shaky data.

Peter Moretti's telephone comments were favorable.

John Anderson's (McDonnell Douglas) telephone comments were favorable, but he requested the addition of the following sentence: "Note that these preliminary cost estimates are our own (SERI's) and are subject to revision by MCAIR as their design efforts continue."

Lou Divone (July 17 SERI Quarterly Review) asked if we planned on carrying out this engineering analysis for other innovative wind systems; the implication being that such plans should be made.

PR-356
August 21, 1979

WORK STATEMENT FOR PROPOSED SERI WORK ORDER

Title: Development Costing of Innovative Wind Turbines

Objective: Develop a methodology for analyzing, assessing, and quantifying the exploratory, advanced, and engineering development costs as part of the life cycle costing of innovative wind systems.

Justification. As part of the SERI task for the Cost Estimating and Engineering Analysis of Innovative Wind Energy Conversion Systems, it is necessary to estimate costs related to the development phase of an innovative wind turbine system's life cycle.

Product: A methodology which will allow the estimation of development costs for an innovative wind system within the context of the Federal Wind Energy Program. A flow chart for using the methodology will be provided and an application of the methodology to an innovative wind system should require approximately five person days.

Approach: The approach is to be detailed in the proposal furnished by potential contractors. It is expected, however, that a review of available DOE and SERI program literature pertaining to innovative wind turbines will be carried out. An assessment of the state of advancement of several systems and a correlation with previously allocated funds (reported in 1979 Dollars) will be made. Information pertaining to conventional horizontal axis machine development and previously designated innovative turbines (Darrieus, Giromill) will also be incorporated into the data base.

Development of costing data for pertinent analogues of wind turbines is to be included.

Costs are to be related to physical parameters, such as material types and weights, dimensions, rated power, etc., for scale models produced and evaluated during the validation phase while engineering development costs are to be related to the production model physical parameters. Design study costs are to be included.

Budget Estimate: $20,000

Project Period: 4 months and 3 months for review

Proposed Schedule: Allow 2 months for internal and external review of proposed work statement
Allow 2 weeks for publication in CBD. (Approximately Nov. 1)
Allow 6 weeks for response
Allow 1 month for contract award

Wind Energy Cost Definition Workshop

Purpose: To establish for the industry, by consensus, cost definitions of WECS components. Hardware, field costs, indirect costs R,D&D, and O&M costs shall be included. The end product will be a published document by SERI/DOE with the definitions which will be available to the general public.

Contributions:

SERI, DOE, EPRI, NASA-Lewis, Rocky Flats, Sandia, AWEA, Boeing, G. E., Kaman, Westinghouse, Alcoa, Hamilton Standard, UTRC, Enertech, Pinson, Windworks, W. T. G., McDonnell Douglas, Lockheed, Grumman, AWEA, and several construction engineering firms (Bechtel, Fluor, Stearns-Roger).

WIND ENERGY COST DEFINITION WORKSHOP (cont.)

Agenda: Presentations on various aspects of wind system costs will be given by invited speakers.

Discussion groups shall review and modify the three preliminary cost definitions lists as required.

Number of Participants:	Approximately 50	
Duration of Workshop:	2 days	
Date:	Mid November, 1979	
Location:	Boulder, Colorado	
Estimated Cost:	Hotel facilities for the workshop:	$1,000
	SERI conference support:	7,000
		$8,000

PR-356
August 21, 1979

UTILITY ANALYTICAL MODELING

David Percival

Objective

Establish the capability to represent wind-derived generation in electric utility generation planning models so that the economic value of the WECS option may be examined.

Approach

Procure established utility generation planning models.

Develop methodology for WECS representation and integrate it into the utility models. Methodology and Modeling is to be acceptable to the electric utility industry.

Output

Report on utility production cost model evaluations

Report on methodology and users manual for the WECS representation

Utility planning model incorporating WECS such that DOE/SERI studies may be performed

Planned Completion - - February 1980

Accomplishments

Utility Models:

Completed and submitted to DOE draft report on utility production cost model evaluation entitled "Electric Utility WECS Analytical Modeling - Production Cost Model Evaluations".

Completed a draft paper entitled "Integration of Intermittent Resources into Baleriaux-Booth Production Cost Models".

WECS Representations:

Received JBF and Stone and Webster models and successfully compiled and duplicated test case for the JBF model.

Tested SIMWEST.

WIND MODEL STATUS

JBF	Verified wind programs with test case supplied. Analyzed coding - very complex.
Stone & Webster	Computer tape received. Began conversion to CDC. Analyzed coding - relatively straight forward.
G.E./EPRI	Tape still not available.
SIMWEST	Executed sample problems. Complicated and cumbersome for our purpose. Not considered further.

FUTURE PLANS

Commence training on PROMOD.

Complete final version of report on "Integration of Intermittent Resources Into Baleriaus-Booth Production Cost Models" and submit to IEEE.

Compare wind models and incorporate selected wind model into value determination methodology.

Discussion on "Integration of Intermittent Resources into Baleriaux-Booth Production Cost Models".

DISCUSSION ON "INTEGRATION OF INTERMITTENT RESOURCES INTO BALERIAUX-BOOTH PRODUCTION COST MODELS"

GOALS

Simplicity

Incorporate intermittent resources (WECS) into a methodology which can utilize a Baleriaux-Booth production cost model (based on load duration curves built from hourly load data).

Keep WECS treatment external to the production cost model.

Capture the random nature of wind speed for long term economic studies.

Incorporate the time of day correlation of wind speed and utility load. (Both show a diurnal cycle.)

Improve credibility with utilities.

Determine whether the greater exactitude in modeling makes a difference in value calculations. The answer to this should be a function of penetration and system mix.

PREVIOUS STUDIES

JBF, G.E., AEROSPACE:
Hourly production cost model with separate LOLP model.

JBF

PRODUCTION COSTS:
Weibull distribution for each hour of typical day per phase. Sequentially subtract expected WECS power for each n portion of power distribution by day type; peak weekday (n=4), average weekday (n=16), saturday and sunday (n-4 each). (See following page.)

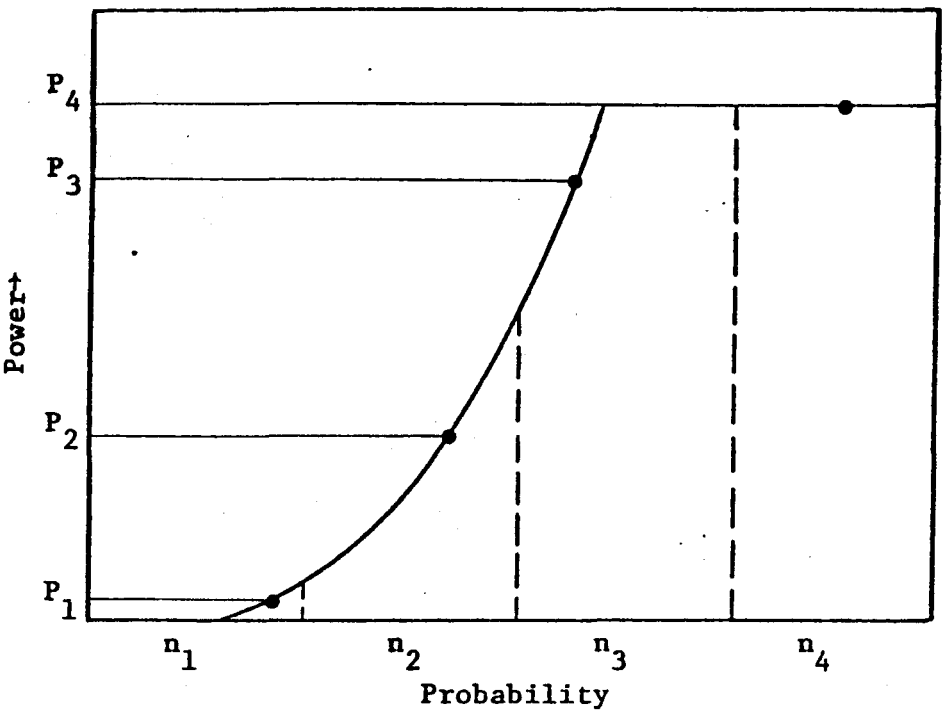
LOLP:
For most critical hour of each weekday, calculate LOLP using three averaged conventional unit types and a distribution of WECS power available.

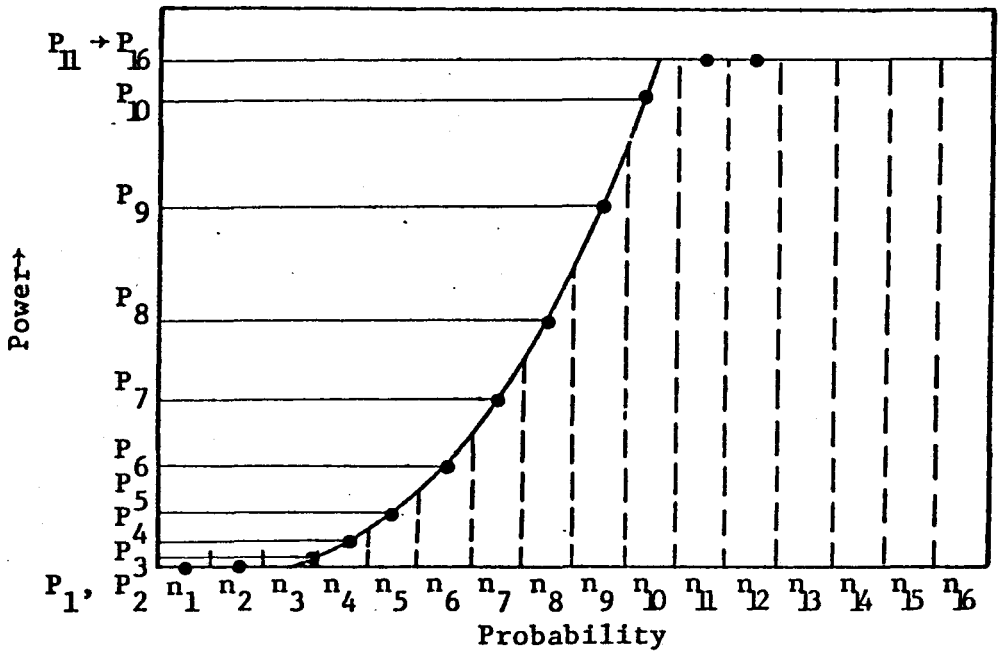
G.E.

PRODUCTION COSTS:
Determined a typical wind year, calculated wind power available hourly and subtracted this from the hourly load.

LOLP:
For all hours during year, calculated LOLP with loads reduced as indicated as above.

JBF UTILIZED WECS PRODUCTION COST POWER POINTS





WECS Power Probability Distribution

AEROSPACE

PRODUCTION COSTS:

A FULL YEAR'S WORTH OF HOURLY WIND SPEEDS WERE DETERMINED FOR A SPECIFIC SITE USING ONE YEAR'S DATA FROM FOUR SITES, WECS POWER DETERMINED FOR EACH HOUR AND SUBTRACT THIS FROM THE HOURLY LOAD.

LOLP:

GENERATED A 22 POINT DISTRIBUTION OF WECS POWER AVAILABILITY FOR EACH HOUR OF TYPICAL DAY FOR EACH MONTH.

ARGONNE NATIONAL LABORATORY:

A SINGLE MODEL TO DO RELIABILITY AND PRODUCTION COSTS.
TWO APPROACHES WERE USED.

SPECIFIC YEAR HOURLY WIND SPEED OBSERVATIONS WERE ASSUMED CONSTANT DURING HOUR, WECS POWER CALCULATED FOR EACH HOUR BASED ON THIS AND SUBTRACTED FROM THE HOURLY LOAD. A TOTAL OF 19 YEARS OF WEATHER DATA WERE ANALYZED SEPARATELY WITH THIS APPROACH. THIS WAS THEIR STANDARD APPROACH.

FROM A NUMBER OF YEARS OF HOURLY WIND VELOCITY DATA, ONE BETA DISTRIBUTION WAS CALCULATED FOR EACH HOUR IN A YEAR. THE EXPECTED ENERGY OUTPUT WAS THEN CALCULATED FROM THE HOURLY BETA DISTRIBUTIONS AND THIS SUBTRACTED FROM THE HOURLY LOAD.

DRAWBACKS OF PAST APPROACHES

Do not capture the random nature of wind speed during an hour.

Generally utilize two models increasing computer time and causing potential data problems.

Lack credibility with the utilities due to modeling problems.

PROPOSED EXTENSION

Develop a wind speed probability distribution for each hour of a typical day for each month.

Convert these to WECS energy availability distributions for each hour of a typical day for each month. The format of this will end up as a set of N bins showing outputs and associated probability of occurrence (like Aerospace LOLP treatment). (See page 110.)

For each of the hourly utility loads, subtract each of the N ouputs of the WECS and keep track of the probabilities. (See page 111.)

Order all of the residuals into load duration curves (LDC) appropriate for the production cost model being used. Also, continue to associate proper probabilities with the points of the LDC. (See page 112.)

If required, segment and arrange the points of the LDC into the format needed by the production cost model being used.

	Hour of the Day					
RATED POWER ↓	1	2	3	23	24	
P_R MW	$P_{1,1}$	$P_{1,2}$				0
.95 P_R	$P_{2,1}$	$P_{2,2}$				.05 P_R
.90 P_R	$P_{3,1}$					.10 P_R
.05 P_R		$P_{21,2}$				.95 P_R
0		$P_{22,2}$				P_R

AVAILABILITY

OUTAGE

$$P_R = \sum_{i=1}^{N=\#WECS\ units} P_{Ri}$$ where P_{ri} is rating of ith unit

Sum of p's in columns should equal one

$$\sum_{i=1}^{22} p_{ij} = 1$$

Each column is the probability distribution of available WECS power for the particular hour.

MONTHLY AVAILABILITY MATRIX FORMAT
BEFORE
CORRECTION FOR SCHEDULED AND FORCED OUTAGE

HOUR 1, NATIVE LOAD = L_1

Residual Loads $(L_1 - P_R)$; $(L_1 - 0.95\ P_R)$; $(L_1 - 0.90\ P_R)$; . . . ; $(L_1 - 0.05\ P_R)$; L_1

Probabilities: $P_{1,1}$; $P_{2,1}$; $P_{3,1}$; . . . ; $P_{21,1}$; $P_{22,1}$

HOUR 2, NATIVE LOAD - L_2

Residual Loads: $(L_2 - P_R)$; $(L_2 - 0.95\ P_R)$; $(L_2 - 0.90\ P_R)$; . . . ; $(L_2 - 0.05\ P_R)$; L_2

Probabilities: $P_{1,2}$; $P_{2,2}$; $P_{3,2}$; . . . ; $P_{21,1}$; $P_{22,2}$

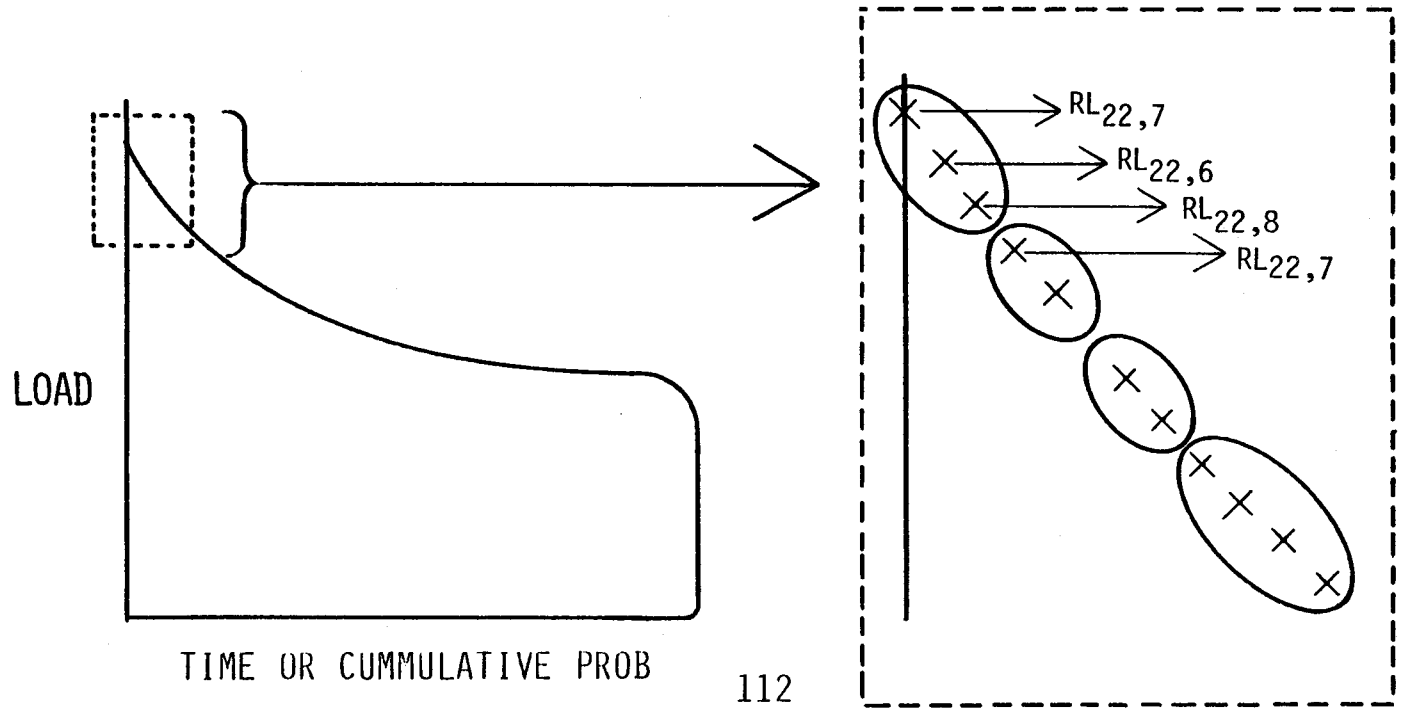
FOR ALL HOURS

AFTER ALL HOURS, PUT ALL RESIDUAL LOADS INTO DESCENDING ORDER. KEEP PROBABILITIES ASSOCIATED WITH RESIDUAL LOADS.

DESCENDING RESIDUALS: $RL_{22,7}$; $RL_{22,6}$; $RL_{22,8}$; $RL_{21,7}$; $RL_{21,6}$; $RL_{21,8}$; $RL_{22,5}$ . . .

PROBABILITIES: $P_{22,7}$; $P_{22,6}$; $P_{22,8}$; $P_{21,7}$; $P_{21,6}$; $P_{21,8}$; $P_{22,5}$ . . .

MAY USE THE DESCENDING RLS AS THE LDC OR CAN BREAK THIS SERIES INTO INTEGER HOUR EQUIVALENTS. PROBABILITIES MAY BE CONSIDERED AS A FRACTION OF HOURS. PROBABILITIES SHOULD BE SUMMED FROM TOP DOWN ($P_{22,7} + P_{22,6} +$ . . ETC.) UNTIL SUM TO ONE. IF NECESSARY, A PROBABILITY MAY HAVE TO BE SPLIT INTO TWO PIECES TO SUM TO ONE EXACTLY. THE ASSOCIATED RESIDUAL LOADS CAN THEN BE PROBABILITY WEIGHTED TO YIELD AN EXPECTED RESIDUAL LOAD.



ADVANTAGES

Incorporates the random nature of wind.

Improves the accuracy of capacity credit and production cost determination while using a single model.

Improves credibility with utilities.

Provides opportunity to account for gust effects and cut-in, cut-out intermittency.

Could provide a means of analyzing and verifying the operation of utility interconnected WECS.

PR-356
August 21, 1979

ECONOMICS OF SWECS TIED TO THE UTILITY GRID

Michael Edesess

Economics of SWECS Tied to the Utility Grid

Objective

Investigate the economics of user-owned, on-site WECS with utility back-up.

Accomplishments

Developed an approach to the problem of evaluating the ecomomics of user-owned WECS which recognizes the relative financial risk of user-owned WECS with utility back-up versus total dependence on utility for power.

Planned Activities

Construct algorithm for assessing the value of on-site WECS, considering utility back-up and buy-back rates, wing regime, load profile and relative WECS financial risk compared with risk of total dependence on utility for power.

Output

Draft report at end of FY79.

User-owned, on-site wind power

Benefits to the user:

Higher penetration of wind power into user's aggregate power demand possible when WECS is user-owned, compared to utility-owned.

User-owned WECS provides economic independence -- i.e., protection against utility rate uncertainties.

Higher penetration of wind power into user's aggregate power demand possible when WECS is user-owned, compared to utility-owned.

Simplified example:

Suppose expected levelized power costs are
- 8¢ per kWh for conventional (utility) generation
- 6¢ per kWh for wind power (utility-owned) generation
- 7¢ per kWh for wind power (user-owned) generation

Suppose utility can achieve 10% penetration of wind power while user can achieve 50% penetration with on-site WECS.

Then user WECS implementation results in 7.5¢ per kWh power cost (8¢ x 50% + 7¢ x 50%) while utility implementation alone results in 7.8¢ per kWh power cost (8¢ x 90% + 6¢ x 10%).

Note that example treats only <u>expected</u> costs of alternatives and does not deal with uncertainties.

USER-OWNED WECS PROVIDES ECONOMIC INDEPENDENCE

I.E., PROTECTION AGAINST UTILITY RATE UNCERTAINTIES

Contemporary financial theory holds that:

(1) A relatively certain cash flow stream is worth as much as a larger, but less certain cash flow.

(Example: A U.S. Treasury bond yielding 8% is worth as much as a small company corporate bond yielding 9%.)

(2) A cash flow stream whose uncertainty is uncorrelated with that of other cash flows in the portfolio is worth more than a cash flow stream whose uncertainty is highly correlated with that of the other cash flows.

(Example: It is better to buy the stock of a plastics company when a lumber company is already in the portfolio than it is to buy another lumber company. Diversification reduces uncertainty.)

How WECS Provide Protection Against Utility Rate Uncertainties

Uncertainty band around expected future utility rates derives from

- Uncertainty in cost of future fuel,
- Uncertainty in cost of future conventional capacity.

These uncertainties are quite large. Deviations from expected rates will be directly related to future general inflation rates and the state of the economy.

Uncertainty band around expected power costs of a WECS purchased today derives from:

- uncertainty in WECS performance predictions,
- uncertainty in WECS maintenance costs.

These uncertainties, while substantial, may have less impact on levelized power costs than the uncertainties about future fuel and capacity costs. Deviations from expectations will be mostly uncorrelated with future general inflation and state of the economy.

Potential Results:

Fully developed WECS may provide a lower level of uncertainty about future power cost than conventional generation.

Deviations from expected WECS power costs are mostly uncorrelated with uncertainties about general inflation and the economy.

Therefore, WECS may be worth as much as conventional generation even at a higher expected power cost.

OTHER BENEFITS OF ON-SITE WECS

Overall Fuel Savings

Widespread on-site WECS use may contribute to technology-pull development of utility WECS market.

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PRODUCTS LIABILITY ISSUES ASSOCIATED WITH SWECS

Robert Noun

Objective

Provide Policy Alternatives for

Department of Energy

Wind Energy Industry

Others

To assure that products liability issues associated with SWECS do not impede their increased use.

SUBTASK 1 - FORMULATE CRITICAL ISSUES

Steps

Analysis of contemporary law

Analysis of potential application of law to SWECS

Identification of issues suggested in steps 1 and 2

Status

Completed

Product

Issue paper circulated in July.

Purpose

Provide basis for analysis of policy alternatives.

Quality Control

Internal SERI review

External review group

SUBTASK 2 - DEVELOPMENT & ANALYSIS OF POLICY ALTERNATIVES

Analyze

Legal problems

Economic impacts

Protection of public

Protection of people who may be liable

Ease of implementation and other
Advantages /Disadvantages of each Alternative

Status

Work has commenced.

Product

Draft report by Mid-September

Purpose

Provide alternatives for discussion.

Consider pros and cons of each alternative without providing recommendations.

Quality Control

Internal SERI review

External review group

SUBTASK 3 - REFINEMENT OF POLICIES

Activities

Consider comments

Further analysis

Relationship among policies

Status

Schedule revised; work to commence Mid-August.

Product

Integrated set of issues and policy alternatives by end of September

Purpose

Provide basis for further action

Quality Control

Internal SERI review

External review group

COMPARISON OF TWO STUDIES

SERI	ROCKY FLATS
Products Liability Issues Associated SWECS	SWECS Product Liability Insurance Assessment
Product Liability Legal Issues Only	Product Liability Insurance Only
Provide Policy Alternatives	Identify Data Requirements
Provide Basic Legal and Policy Background	Build Upon SERI Task

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ENVIRONMENTAL IMPACT ASSESSMENT OF SMALL WIND ENERGY CONVERSION SYSTEMS

Kathryn Lawrence

Objectives

Identify potential life-cycle ecological and health impacts of small WECS (less than 100 kW) deployed as stand-alone systems and interconnected to utility grids.

Determine the environmental implications of ecological and health impacts.

Define potential environmental barriers to small WECS deployment.

SUBTASK 1: ASSESSMENT OF EFFECTS ON HUMANS

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Steps

Quantify materials required for system manufacture and operation.

Calculate emissions from materials acquisition and processing.

Evaluate health risk from emissions.

Determine injury and accident incidence from manufacture, installation, and operation by applying appropriate industrial statistics.

Assess risk of small WECS operation to human populations (e.g., potential injuries from blade failure).

Determine aesthetic impact of SWECS by conducting a nonrandom survey of visitors to the Rocky Flats Wind Test Site.

Status

Work has begun; the consultant (Jerome Weingart of LBL) has been obtained to independently verify SERI risk assessments.

Aesthetics Survey has been developed and submitted to SERI's Survey Review Committee and Rocky Flats for approval; the survey was also sent to R. Ferber, Univ. Ill., for review.

Inhouse efforts on schedule; results to be presented in task Progress Report, September 1979.

Product

Summary of life-cycle environmental health effects to be presented in the Draft Final Report, Mid-December 1979.

Purpose

Provide health risk estimates to be integrated with ecological effects estimates.

Quality Control

Internal SERI review

Review by selected, external professionals: to be selected

DOE review of Draft Final Report

SUBTASK 2: ASSESSMENT OF ECOLOGICAL EFFECTS

Steps

Review existing SWECS ecological effects and technological data.

Contact selected SWECS manufacturers to determine if environmental problems have been encountered.

Examine and quantify where possible potential ecological effects on:

Land use: requirements of towers; safety zones, multiple SWECS deployment; soil erosion; reclamation following SWECS decommission

Air quality. Indirect effects from use of exotic materials during SWECS manufacture; noise; EM interference

Water quality: soil erosion and runoff during construction and operation; release of toxic fluids (e.g., storage media if used)

Biota: displacement or destruction of plant and animal communities and habitats; release of toxic substances throughout life-cycle; effects of rotor blades.

Status

Work has begun results of literature review will be presented in the Progress Report.

Graduate Summer Intern joined subtask team June 1, 1979.

Product

Qualitative and Quantitative Analysis of the life-cycle ecological effects of SWECS; effects will be integrated with health risk estimates and presented in the Draft Final Report, Mid-December 1979.

Purpose

Provide ecological effects estimates to be integrated with health risk estimates.

Quality Control

Internal SERI review

Reveiw by selected, external professionals: to be selected.

SUBTASK 3: LIFE-CYCLE ENVIRONMENTAL ASSESSMENT

Activities

Analyze environmental implications of health and ecological effects estimates for each life-cycle phase, SWECS design option, and deployment option.

Develop a ranking system for each life-cycle phase which incorporates the quantitative estimates of effects and emission with the duration of each phase.

Status

Scheduled to begin October 1, 1979

Product

Integrated SWECS life-cycle environmental effects estimates to be presented in the Draft Final Report, Mid-December 1979.

Purpose

Provide detailed information on potential environmental barriers and benefits of SWECS deployment.

Quality Control

Internal SERI review of Draft Final Report

Peer review of Draft Final Report: Reviewers to be determined

DOE review of Draft Final Report

SUBTASK 4: VIDEO FILM OF WECS TV INTERFERENCE

Activities

Provide a 15-minute color video film to SERI and DOE which presents the potential origin and TV interference of the Block Island wind turbine generator (WTG).

film will identify what are and are not probable effects.

audience will be Block Island residents and other interested laymen.

Status

University of Michigan Radiation Laboratory (Thomas Senior) was selected for preparation of the film; subtask effort was completed during June.

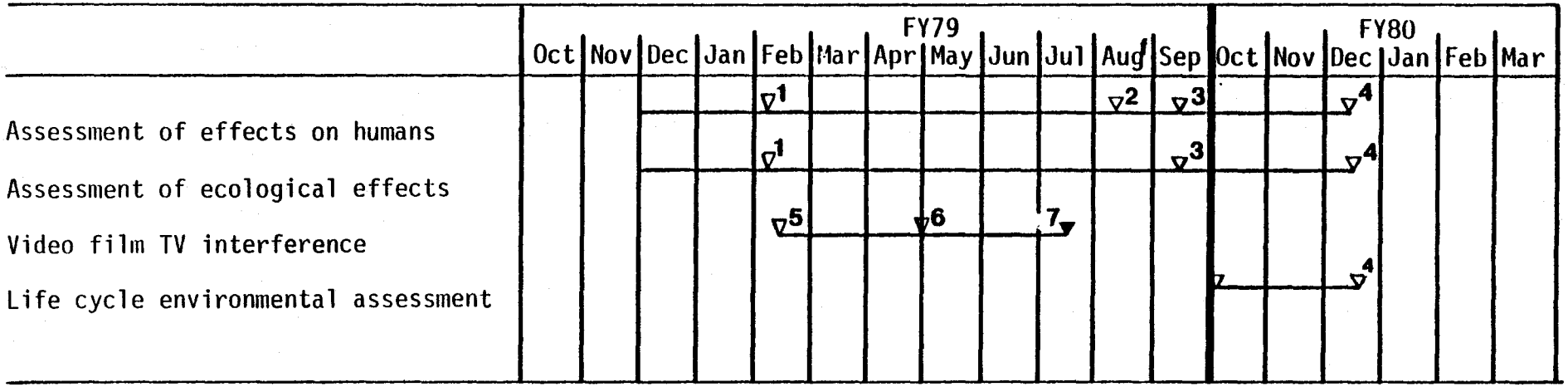
Product

A 15-minute color videocassette presenting potential TV interference of the Block Island WTG was provided to SERI and DOE/WSB on June 1, 1979; film was revised and delivered approximately June, 13, 1979.

Quality Control

Film reviewed, modified, and revised version approved.

ENVIRONMENTAL IMPACT ASSESSMENT FOR SMALL SYSTEMS*



*Task redefined March/April '79
to incorporate WSB/DOE comments.

1. Collect data
2. Final selection of SWECS designs and deployment options for study
3. Interim Report
4. Draft final report
5. Initiate preparation of TV interference film
6. Issue subcontract
7. Complete TV interference film

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August 21, 1979

SOLAR COST DATA BANK

Joseph Lavender

SOLAR COST DATA BANK

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August 21, 1979

(TECHNOLOGY CHARACTERIZATION)

Objectives

Establish a methodology to assure a consistent and high quality source of technology characterization across DOE.

Scope

Effort will include: initial and, when possible, detailed engineering designs (e.g., r.p.m., rated power kW/yr and average kW/yr), economic (e.g., capital cost, O&M) and environmental (e.g., acres of land per installation) parameters for all technologies supported by the Department of Energy.

Methodology for establishing and maintaining a technology characterization data base for various implementation rates and applications shall be included.

Accomplishments

Energy costs and technical information was included in the solar cost data bank for the Kaman and General Electric (500 kW and 1500 kW) design studies. The energy cost as determined was intended to serve as a reference point for future comparison with other utility generating systems.

Initiated a SERI review of construction and manufacturing costs of MOD-2 components by a meeting with staff from NASA-Lewis.

Accomplishments (Cont'd)

Started an in-house study of large systems tower costs based upon prior work conducted by Stearns Roger, Rockwell International, Martin Marietta, and General Electric. Will be integrated with "soft" tower designs.

Planned Activities

Review construction and manufacturing cost information (MOD-2) with Boeing Staff. Include MOD-2 in the solar cost data bank (technology characterization).

Perform a manufacturing cost optimization study on several existing small wind energy conversion systems. Eventually include vertical axis, SWECS, and innovative design in the effort.

Establish cost relationships for various major components of large horizontal and vertical axis wind systems.

Output

A capability to rapidly determine manufacturing facilities required for large wind systems as a function of production quantities and schedules.

Cost relationships for various major components of horizontal axis and vertical axis wind systems.

A revised cost for current small wind systems as a result of high production rates.

SOLAR COST DATA BANK PROGRAMS

Analysis Division

Biomass - Energy derived from growing organisms (Wood, corncobs, seaweed, etc.) Methanol, Ethanol, Gasohol, Digesters

Wind - Electrical and Mechanical energy conversion

OTEC - Energy from thermal gradients between various ocean depths

Photovoltaics - Direct conversion of solar radiation into electrical energy by solar cells

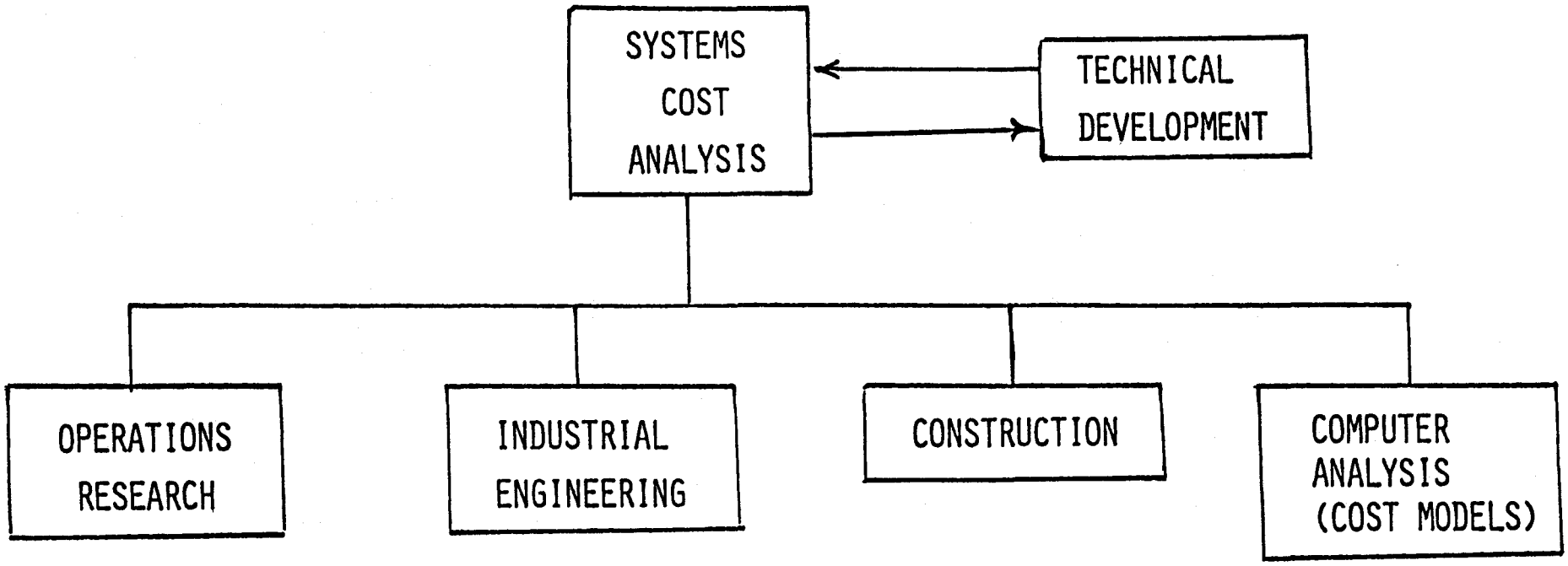
Solar Collectors - Feeds thermal energy into central power generating equipment

Other SERI Activities

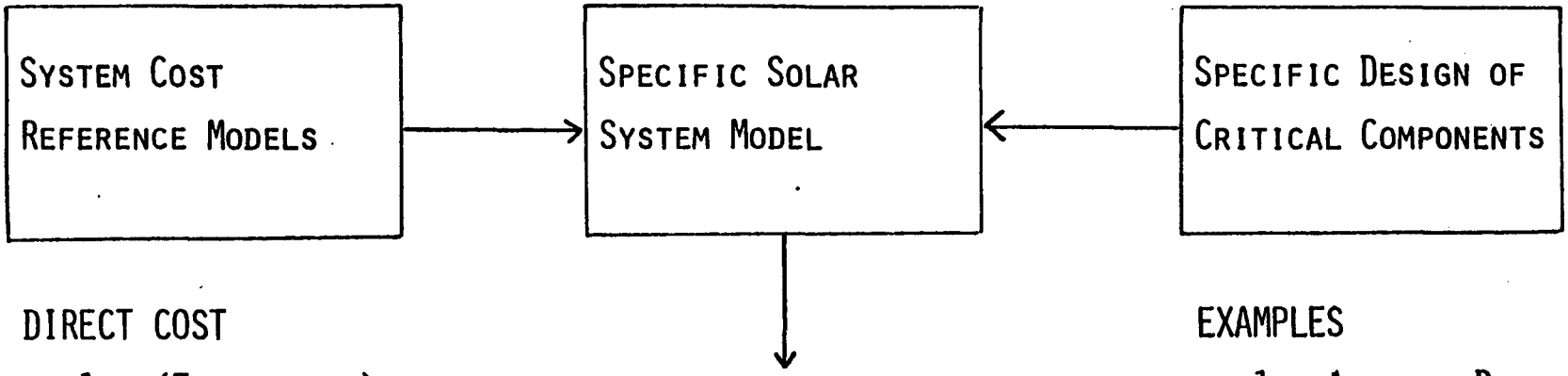
Saudi/U.S. Joint Program

Economic & Market Analysis Branch

SYSTEMS COST ANALYSIS ORGANIZATION (SPECIALTY)



SOLAR COST MODELING



DIRECT COST

1. (Excavation)
2. (Concrete)
3. (Structural Steel)
4. (Piping)
5. (Electrical)
6. (Building)
7. (Painting)
8. (Insulation)

INDIRECT COST

1. Craft Benefits
2. Small Tools
3. Equipment
4. Construction Management
5. Temporary Facilities, Etc.

EXAMPLES

1. Azimuth Drive
2. OTEC Heat Exchangers
3. Optimize Field Installation

SERI COST COMPARISON

The site of Houston, Tex., is the location for all SERI base cost comparisons. A single site has been selected to ensure that all cost considerations, both direct and indirect, have been included.

Adjustments will be made from the SERI comparison cost for specific site applications.

MULTIPLE BASIC ORDERING AGREEMENT

Subcontracts for technical personnel to provide rapid response analysis support within various solar activity areas.

The areas for all analysis include:

- Operation and Analysis of Solar Market Penetration Models
- Solar Electric value Analysis
- Manufacturing Cost Studies
- Studies of Public Opinion
- Market Studies
- Economic Analysis of Biomass
- Macroeconomics Analysis
- Decision Analysis
- Construction Cost Studies
- Program Evaluation
- Economic Analysis of Cost Reduction
- Electric Utility Taxation and Regulation
- Operations and Maintenance Costs of Solar Systems

Possible areas for work in wind during FY(80) includes:

- Manufacturing Cost Studies
- Construction Cost Studies
- Economic Analysis of Cost Reduction
- Operations and Maintenance Costs of Solar Systems