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Economic Analysis of Darrieus Vertical Axis Wind Turbine Systems for the Generation of Utility Grid Electrical Power

Volume IV—Summary and Analysis of the A.T. Kearney and Alcoa Laboratories Point Design Economic Studies

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ECONOMIC ANALYSIS OF DARRIEUS VERTICAL AXIS WIND TURBINE SYSTEMS FOR THE GENERATION OF UTILITY GRID ELECTRICAL POWER

VOLUME IV - SUMMARY AND ANALYSIS OF THE A. T. KEARNEY AND ALCOA LABORATORIES POINT DESIGN ECONOMIC STUDIES

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Acknowledgment

Sandia-administered contracts with A. T. Kearney, Inc. and Alcoa Laboratories provided the underlying content of this report. The A. T. Kearney study was conducted primarily by John Ashby and Louis Saiia. Key participants in the Alcoa study were James Alster, Marshall Klingensmith, Howard Kutcher, Sue Lowers, and Paul Vosburgh. Richard Braasch, Emil Kadlec, Bernard Stiefeld, and Gerald McNerney of Sandia Laboratories provided administrative and technical contributions. D. D. Teague of DOE monitored the study and provided substantial guidance throughout.

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Contents

Abstract

The A. T. Kearney and Alcoa economic studies are two independent attempts to assess the installed costs of a series of six Darrieus vertical axis wind turbine designs. The designs cover a range of sizes with peak outputs from 10 to 1600 kW. All are designed to produce utility grid electrical power.

Volume IV of this report summarizes, compares, and analyzes the results of these studies. The Kearney and Alcoa final reports are included in the Appendices.

Preface - Objective and Organization of the Vertical Axis Wind Turbine (VAWT) Economic Study

The ultimate objective of the VAWT economic study is to determine as accurately as possible the profitable selling price of Darrieus vertical axis wind energy systems produced by a typical manufacturing and marketing firm. This price may then be compared to the electrical utility energy saved by the system to allow potential users to assess the usefulness of the VAWT concept. The basic approach for assessing the selling price is through a detailed economic analysis of six actual system designs. These designs cover a wide range of system size points, with rotor diameters from 18 to 150 ft., corresponding to approximate peak output ratings from 10 to 1600 kW. All these systems produce 60 Hz utility line power by means of induction or synchronous generators coupled mechanically to the rotor and electrically to the utility line.

Two independent consultants in parallel conducted the economic analyses of these point designs. A. T. Kearney, Inc., a management consulting firm, provided analyses for the four largest point designs; Alcoa Laboratories considered all six design points. Both studies attempt to determine a reasonable selling price for the various systems at several production rates ranging from 10 to 100 MW of peak power capacity installed annually. In addition, the consultants also estimated the costs of constructing one or four preproduction prototypes of each point design. Toward this objective, the consultants considered a hypothetical company to procure components; perform necessary manufacturing; and manage the sales, marketing, delivery, and field assembly of the units. Profits, overhead, and administrative costs for this hypothetical company are included in estimating the appropriate selling price for each point design.

Sandia Laboratories selected the basic configurations of the point designs (i.e., the number of blades, blade chord, rotor speed, etc.) and developed specifications for the configurations using an economic optimization model that reflects the state-of-the-art in Darrieus system design. The computer-adapted optimization model uses mathematical approximations for the costs of major system elements and the energy collection performance of the system. The model effects cost vs performance trade-offs to identify combinations of system parameters that are both technically feasible and economically optimal.

System configurations identified by the optimization model served as a starting point for all the point designs. Sandia Laboratories completed the designs for the four largest systems (120, 200, 500, and 1600 kW) and Alcoa Laboratories prepared the two smallest systems (10 and 30 kW). The level of detail associated with each design is commensurate with an adequate determination of component costs and not necessarily with what is required for actual construction of the systems.

This final report is divided into four separate volumes, corresponding to overall organization of the study:

Volume I	The Executive Summary - presents overall conclusions and summarizes key results.
Volume II	Describes the economic optimization model including details of system performance calculations and cost formulas used in the optimization process. The model-estimated costs per kilowatt hour of the optimized systems are presented as a function of the rotor diameter, and the dominant cost and performance factors influencing the results are discussed. The volume concludes with a tabulation of optimized performance and physical characteristics of the point designs.
Volume III	Presents the actual point designs and discusses major design features. Tabular data on energy production, component weights, and component specifications are included.
Volume IV	Summarizes results provided by the cost consultants' analyses, interprets observed trends, and compares results with those from the economic optimization model.

1. Introduction and Conclusions

The economic analysis of a set of Darrieus VAWT designs was contracted to A. T. Kearney (a management consulting firm) and Alcoa Laboratories (a product development laboratory). Both of these consultants have expertise in estimating costs of fabricated components as well as the profits and indirect costs that are built into a business organization controlling the manufacturing, marketing, and delivery of production systems.

The approach used by the consultants was to obtain baseline prices for major system components through quotations from specialized manufacturing firms. These delivered prices were then loaded by the business-oriented costs associated with a hypothetical wind turbine company. For unusual parts dissimilar to anything being manufactured, the consultants made their own estimates of the probable manufactured cost. This report summarizes and compares the results obtained by the consultants.

The consultants operated independently under ground rules designed to facilitate comparisons of the two analyses. Section 2 describes the standardization of VAWT design, production rate, and market scenario upon which the studies are based. Six point designs were provided by Sandia's optimization studies (Volumes II and III) which ranged in size from 10 to 1600 kW in peak electrical output. Production volumes considered were 1 and 4 units (preproduction prototypes), and annual continuous production rates of 10, 20, 50, and 100 MW of peak installed capacity. The market scenario defined concentrated and distributed users of the VAWT.

Section 3 summarizes results of both investigations. Results are reduced to a common format based on final reports prepared by the consultants. The final reports are contained in Appendices B and C of this volume for A. T. Kearney and Alcoa, respectively.

The agreement between the consultants on their estimates of total installed system costs is generally good. The cost of energy* is surprisingly similar for the five largest point designs (30, 120, 200, 500, and 1600 kW) at the highest production rate, although small but definite economies of scale are observed. The projected cost of energy of the 1600 kW design is from 10 to 20% less than that for the 30 kW machine. In view of the overall accuracy of the study and the modest economies of scale predicted, this study is not interpreted as conclusive proof that the largest

*The cost of energy calculated in Section 3 is simply defined as 15% of the total installed cost divided by annual energy delivered by the system. A more elaborate definition of the cost of energy is presented in Section 6.

point design is the most promising. Additional design and development work on larger systems is warranted to verify the observed trend.

The smallest system (10 kW) has a predicted cost of energy substantially higher than that for the larger systems. Apparently, components such as the electrical controls and certain labor-intensive items are relatively insensitive to system size and tend to dominate the cost structure of smaller units. The commercial future in a utility grid application of such small machines relative to the larger ones is dependent on the existence of markets willing to pay the cost penalty for compact units and/or the development of technical improvements that reduce fixed production costs.

While the A. T. Kearney and Alcoa investigations are in good agreement with regard to total system price, the consultants' estimated prices of certain individual system components do differ by as much as 200%. The large discrepancies are generally caused by different estimating assumptions and/or misunderstanding of the specifications appropriate to that component. In the case of vendor quotes, the vendor's view of the seriousness and competitiveness of the inquiry may produce substantial variations in the quoted price.

In Section 4 an attempt is made to analyze the most serious discrepancies. Several modifications related to misunderstood specifications are invoked upon the A. T. Kearney and Alcoa studies, and their impact on the overall study conclusions discussed. Other discrepancies related to different estimating assumptions remain and are an inevitable part of the subjective estimating process. The areas with the most disagreement appear in the estimates of installation costs and in contingencies applied to account for technical uncertainties.

There is reasonable agreement between the consultants' results and the predictions of the economic optimization model presented in Volume II. Section 5 discusses this comparison and itemizes areas where changes might improve the accuracy of absolute cost predictions by future versions of the economic optimization model. It is shown in Section 5 that the optimized design points indicated by current versions of the model are consistent with the consultants' results.

The final section (Section 6) considers the effect of operation and maintenance and the capital cost of automatic controls on the cost of energy for the point designs. This section is intended primarily to put this study on a common ground with other DOE-sponsored studies of this type. The cost of energy calculation in Section 6 is based on annual charges of 18% of the installed capital costs plus levelized*

*The O&M costs are estimated in 1978 dollars. A levelization factor of 2.0 is applied to these estimates to account for inflation in O&M costs which will occur over the lifetime of the system.

annual operation and maintenance (O&M) costs. These annual costs are divided by the annual energy production of the system to yield the cost of energy. A system availability of 90% is assumed to calculate the annual energy production.

The cost of energy yielded by this formula is about 25% higher than the costs presented in other sections of this report. The best systems produce energy according to the new formula in the range of 4-6¢/kWh in a 15 mph median windspeed site. The largest systems also look more favorable in this formulation because the levelized O&M costs are relatively independent of system size and tend to penalize smaller systems.

The overall conclusions reached by the analysis of the A. T. Kearney and Alcoa studies are summarized as follows:

- The system cost estimates appear to be reasonable and suggest that the technology imbedded in the point designs can, in production, provide energy in the range of 4-6¢/kWh in a 15 mph median windspeed environment.

- The accuracy of the estimates represent typical industrial practice used to establish feasibility and probable costs of a new technological product. The inconsistencies between the two studies are of a subjective nature. The elimination of the inconsistencies will occur only with expansion of the experience and technical base on Darrieus VAWT systems.

- The results indicate small but significant economies of scale associated with the largest systems investigated. An optimum size system was not identified by the consultants. Examination of the trends in the data and experience with the economic optimization model (Volume II) suggests that the most cost-effective systems using the technology in the point designs are in the range of 100-200 feet in diameter.

- The conclusions of this study are only valid for the ground rules stated in Section 2 and for the technology of the point designs.

2. Study Ground Rules

Both consultants were to analyze each of the four Sandia point designs, referred to as the 120, 200, 500, and 1600 kW units (Fig. 2.1). The Alcoa study has a larger

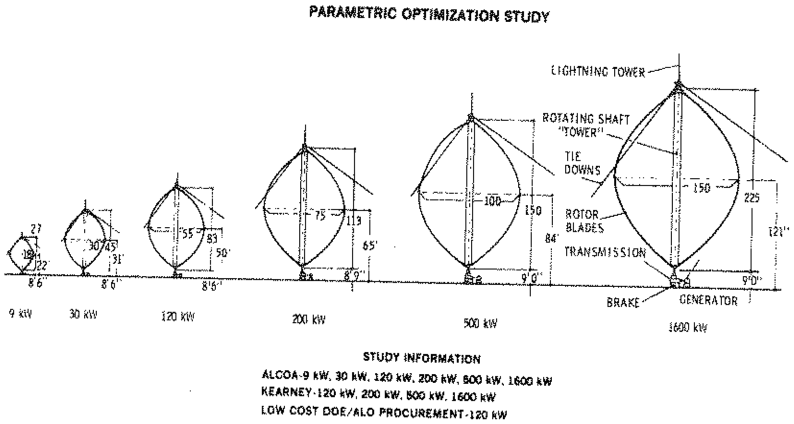


Figure 2.1 - Dimensions of the Six Point Designs (Power Ratings are Nominal)

scope in that two additional smaller machines were also investigated (10 and 30 kW nominal rated power, respectively). Alcoa designed these smaller machines as part of their study and Sandia supplied dimensions of critical structural components.

Design details for the point designs are provided in Volume III of this study. In the interest of accuracy, the point designs are biased toward manufacturing technologies either in common use or which have been demonstrated to be feasible in existing operating systems. This should be recognized as an implied conservatism in this study, since there are undoubtedly other technologies, as yet unexploited in this application, which can potentially reduce costs.

Although the consultants were requested to use the point designs as a starting baseline, exploration of more economical design alternatives for specific components was encouraged. Incorporation of such alternatives into a design was subject to Sandia approval.

A narrative description of the point designs and tabular specifications on all "shelf" components were supplied in addition to the design drawings at the start of the consultants' contracts. The narrative (Appendix A of this volume) contains several design-related ground rules governing items such as site-available utility line voltage, types of generators, and fencing requirements.

To assess the business-related costs of producing the point designs, the consultants were required to construct a "business scenario." This scenario outlines the procurement, manufacturing, and marketing tasks of a hypothetical wind turbine production company referred to as VAWT, Inc. The profits, overhead, and direct costs associated with the flow of materials and services through this company were to be accounted for in determining a profitable selling price for each point design. The only requirements placed by Sandia on the business scenario were the production rates and customer types appropriate for VAWT, Inc.

The production of turbine systems was specified to be at rates of 10, 20, 50, and 100 MW of installed peak nominal capacity per year. Annual production rate rather than total production was used because wind turbine marketing and production are naturally continuous, rather than single batch processes. Production was specified in terms of total megawattage (rather than number of units) because the market demand is more directly related to total capacity. The consultants were also to estimate installed costs of 1 or 4 preproduction prototypes of each point design.

In general, each point design was to be considered at each production rate as the sole product of VAWT, Inc. However, Alcoa also considered production costs for VAWT, Inc. producing a family of rotor sizes in quantities leading to the same annual installed capacity. The quantities of each rotor size in a family were selected so that sales of each point design contributed equally to the total annual installed capacity.

Sandia specified two customer types. The first type, a "concentrated user," represents the utility or industrial user who requires an entire year's production of VAWT, Inc. Turbines for this user were assumed to be concentrated on a wind turbine "farm" located an average distance of 250 miles from the plant. The second type of customer, the "distributed user," represents farms, individuals, small industries, etc. that would require only a very small fraction of the annual production. The Kearney study considered only concentrated users, as such users are more likely to be interested in the larger (120, 200, 500, and 1600 kW) point designs. Alcoa sold the two smallest systems (10 and 30 kW) only to distributed users, and the two largest (500 and 1600 kW) only to concentrated users. The intermediate units (120 and 200 kW) were considered for either market.

The consultants were to compile the direct and indirect costs required to provide a turnkey system to a customer at his site. The compilation does not include land costs and assumes the site is already serviced by appropriate roadways and utility lines. A uniform reporting scheme on costs was outlined for a comparison of the two consultants' results. Costs were to be divided into subsystems consisting of the blades, cable tiedowns, central tower, transmission, generator and electrical controls, and field work (foundation, assembly, and erection). Appendix A outlines the division of specific components into these subsystems.

The Alcoa and Kearney contracts lasted 5 and 3 months, respectively. The longer duration for the Alcoa contract was appropriate considering the expanded scope of work on the number of point designs and business scenarios investigated. All costs reflect the state of the economy at the time of the study; i.e., the summer of 1978.

The major deliverable output of the studies was a final summary report and compilation of any backup data used in the development of final results.

3. Results

Final reports received from A. T. Kearney and Alcoa in September 1978 are included in Appendices B and C of this volume. Not included in this report because of their size are voluminous collections of backup data.

The major purpose of this chapter is to summarize the consultants' results and methods in a common format to aid the reader in interpreting and comparing results. For additional detail, the reader may refer to Appendices B and C.

3.1 Business Scenario Definition and Accounting Methodology

A. T. Kearney's business scenario constructs VAWT, Inc. as a management, purchasing, warehousing, and marketing firm. Virtually all manufactured components of the point designs are contracted. Technical tasks of VAWT, Inc. are limited to inspection and kitting of suppliers' components for shipment to the site.

Kearney's cost estimations consist of obtaining direct quotes from suppliers capable of manufacturing each component. Imbedded in these quotes are the profits and overhead of the suppliers. To these quotes, an overhead (10%) and profit (10%) associated with the administration of VAWT, Inc. are added. Any direct expenses by VAWT, Inc. necessitated by shipping, inspection, or packaging requirements are loaded by labor overhead (110%), administrative overhead (34%), and profit (7%), and are added to the adjusted quotes.

Suppliers were generally requested to quote for delivery of fixed quantities of components corresponding to the annual requirements appropriate to VAWT, Inc.

Quotes were not obtained on every system component because of the great number of components involved in each point design, the study time scales, and the price-quoting capacity of industry. For these unquoted items, Kearney estimated typical supplier profits and prices for labor, materials, and factory overhead. Kearney also estimated the cost of some components based on factoring quotes in proportion to weight from the corresponding component on another point design. Included in their final report are the identification of components with prices estimated from quotes, Kearney estimates, and weight factoring (or a combination of the three methods).

The business scenario used in the Alcoa study differs from the Kearney concept. Alcoa considers a vertically integrated VAWT, Inc. with substantial manufacturing capabilities in addition to its distribution and marketing tasks. Manufacturing tasks of the firm include fabrication of all wind turbine components except unfinished blade extrusions and shelf items such as transmissions, generators, brake calipers, couplings, and cables.

Alcoa's cost estimates are based on manufacturers' quotes for virtually all components. To arrive at manufacturing costs associated with the Alcoa scenario, quotes obtained on the specially fabricated components are reduced using Alcoa's estimate of the profits, overhead, and direct labor charges associated with the quoting firm. Then VAWT, Inc. profits, overhead, and labor are added to this modified quote. Overhead and profit for VAWT, Inc. are estimated from a tabulation of expected business expenses, total sales, and profits.

In general, the overhead expenses of VAWT, Inc. are greater in the Alcoa study than in Kearney's (see Section 3.2) because of the substantial manufacturing function given to VAWT, Inc. in Alcoa's scenario.

Alcoa constructed a scenario for the four smallest designs (10, 30, 120, and 200 kW) marketed to distributed users. The price computations are very similar to the concentrated user case, except that an additional distribution cost is added to the selling price. This cost is estimated for distribution of the systems through an agricultural co-op.

The Alcoa and Kearney studies differ somewhat in the number of units produced by VAWT, Inc. This is shown in Table 3.1, where the numbers of units produced

Table 3.1

VAWT, Inc. Annual Production Quantities
For the Alcoa and Kearney Studies

Point Design (kW)		Production Rate (MW/yr) 10	20	50	100
10	(Alcoa)	480	1130	3330	7460
30	(Alcoa)	310	740	2175	4831
120	(Alcoa)	84	196	580	1285
	(Kearney)	83	170	420	830
200	(Alcoa)	46	108	317	704
	(Kearney)	50	100	250	500
500	(Alcoa)	18	42	122	270
	(Kearney)	20	40	100	200
1600	(Alcoa)	6	16	44	99
	(Kearney)	6	12	31	62

annually are given as a function of annual production rates. The differences are due to Alcoa's determination of production quantity to yield a specified annual revenue (5, 10, 25, and 50 million dollars/year) rather than installed capacity. Considering the modest learning benefits observed (see Section 3.2) the differences in production rate are not considered significant.

3.2 System Price Summary and Comparisons

Table 3.2 summarizes subsystem and total installed cost results for the 100 MW/yr production rate as estimated by A. T. Kearney and Alcoa.

The A. T. Kearney results in Table 3.2 are as they appear in Appendix B. Alcoa results from Appendix C have been adjusted for consistency with the format of Table 3.2 because Alcoa adds to the sum of direct component production and purchasing costs a total overhead and profit expected for the operations of VAWT, Inc. It is therefore necessary to distribute this total overhead and profit over each subsystem direct cost to permit subsystem-by-subsystem comparison in Table 3.2. Distribution among the system components is accomplished as follows: for purchased components (the generator, tiedown cables, and the drive train) 21% of the direct cost* was taken out of the per-machine overhead and profit and added to direct component cost. For VAWT, Inc. fabricated items (the tower, blades, electrical controls), the remaining overhead and profit is distributed in proportion to the fabricated item cost. The net effect of this manipulation is to yield an estimate of subsystem costs that include overhead and profit. Of course, total system costs shown in Table 3.2 are unaffected by this manipulation and are identical to the Alcoa results given in Appendix C.

The majority of Alcoa's results in Appendix C are for production scenarios where VAWT, Inc. distributes a mixed product line of point designs. However, to facilitate comparisons with A. T. Kearney, the Alcoa results in Table 3.2 and elsewhere in this summary are for a production scenario where the entire production of VAWT, Inc. is devoted to a single point design. This production case appears in the Alcoa report as an addendum to Appendix C.

For the 120 and 200 kW designs, Alcoa considered both the concentrated and distributed user markets (see Section 2). Results summarized in Table 3.2 are for the concentrated user market. The total system costs for the distributed user scenario are 5 to 10% lower due to reduced installation costs anticipated in sales to distributed users.

*The percentage load for VAWT handling of purchased items is taken as 21% to be comparable with the A. T. Kearney study.

distributions are height-corrected from a 30' reference height to the rotor centerline with a 0.17 wind shear exponent. A sea level air density (0.076 lbm/ft^3) is used to determine rotor shaft output. Generator and transmission losses are accounted for as discussed in Volume II. Annual cost to the user (including financing, maintenance, and operating expenses) is assumed to be 15% of the installed selling price. Other methods for calculating cost of energy which separately consider costs of financing and operating expenses are discussed in Section 6.

The point designs are actually optimized for the 15 mph distribution, but system cost per kilowatt hour in 12 and 18 median windspeed distributions are also shown in Fig. 3.2. In the 12 and 18 mph distributions, the turbine operating mode and hardware are assumed to be the same as for the 15 mph distribution. Thus, the 12 and 18 mph systems are not, strictly speaking, optimized. However, the reduction in cost of energy possible through complete optimization in the 12 and 18 mph distribution is only the order of 10% (see Volume II for additional details). The annual system energy outputs (MWh) used for the results of Fig. 3.2 are given in Table 3.3.

Table 3.3
Annual Energy Output (MWh/yr) of Point Designs
Used for Derivation of Figs. 3.2, 3.4

System Size (kW)	Median Windspeed (mph)		
	12	15	18
10	6.84	13.7	21.6
30	26.8	51.6	78.9
120	132	246	368
200	263	490	731
500	553	1070	1630
1600	1590	2950	4370

The lack of smoothness in these curves is due to a combination of the general uncertainty of the cost-estimating process and the fact that many component costs vary with size in a step-like manner as manufacturing and/or shipping constraints are encountered.

Both studies indicate that the cost per kilowatt hour is only modestly dependent on rotor size for rotor diameters > 30 ft., with small but definite economies of scale that persist up to the 1600 kW system.

The Alcoa study demonstrates that the smallest machine is markedly less cost-effective than the larger units. This is due to the tendency of smaller systems to be dominated by cost elements that increase much slower with increasing rotor size than does the annual energy-collecting capacity of the rotor. The principal cost elements producing this effect in Alcoa's study are the labor charges on all components, the generator and electrical controls, and the speed-increasing transmission. It follows that design and/or manufacturing developments that can reduce these size-insensitive costs will improve the cost-effectiveness of the smaller machines.

Table 3.4 and Fig. 3.3 summarize results from the two studies for the 10 MW/yr

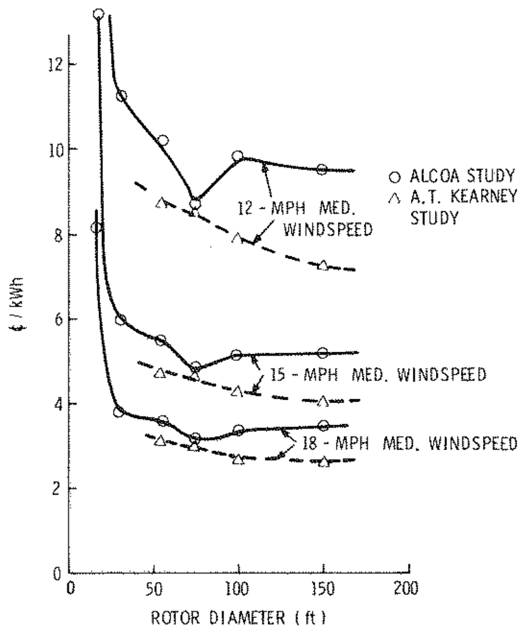


Figure 3.3 - Cost per Kilowatt Hour for the Point Designs - 10 MW/yr Production Rate

production rate. The results are similar to results for the 100 MW/yr rate, although there is more divergence between Alcoa and Kearney on the two largest systems in the 10 MW/yr case. Apparently, Alcoa has assumed that the "learning" benefits associated with higher production rates are more significant on the largest machines. This is not unrealistic, as costs for the largest point designs are less dominated by shelf (low-learning-rate) components than are the smaller machines.

Figure 3.4 shows the effect of production rate on cost of energy for the 120 kW point design. The Alcoa results indicate a slightly more rapid decrease in cost with increasing production. The Kearney study estimates the production cost decay either by analysis of vendor cost quote dependence on quantity ordered or in accordance with component-by-component estimates of reduced per-unit tooling costs and anticipated learning. Alcoa used similar methods but also included additional economies of scale in the overhead associated with VAWT, Inc. These effects are shown in Fig. 3.5 which

Table 3.4

Component Cost Summary
10 MW/yr Production (K $)

Nominal System Size (kW)	Source	Blades	Tower	Drive	Tiedown	Electrical	Delivered Selling Price	Foundation	Erection	Total
10	Alcoa	1.0	2.8	2.7	.6	2.0	9.1	1.3	1.5	11.9
30	Alcoa	3.2	5.0	4.3	1.3	2.5	16.3	2.4	1.6	20.3
120	Kearney	7.5	13.4	13.6	10.1	11.1	55.7	10.9	10.5	77.1
	Alcoa	18.4	9.4	19.6	2.9	9.6	59.8	16.0	14.0	89.8
200	Kearney	16.1	22.5	29.3	24.6	33.8	126.3	11.0	13.4	150.7
	Alcoa	31.4	25.5	30.9	6.7	14.7	109.1	24.5	20.5	154.1
500	Kearney	36.2	45.0	73.7	49.9	43.5	248.3	14.2	29.2	291.7
	Alcoa	59.1	80.0	67.0	17.5	61.9	285.5	45.0	37.0	367.5
1600	Kearney	185.6	114.1	190.9	155.8	37.4	683.8	33.2	49.3	766.3
	Alcoa	234.8	232.4	214.8	48.4	89.6	820.0	133.0	67.0	1020.0

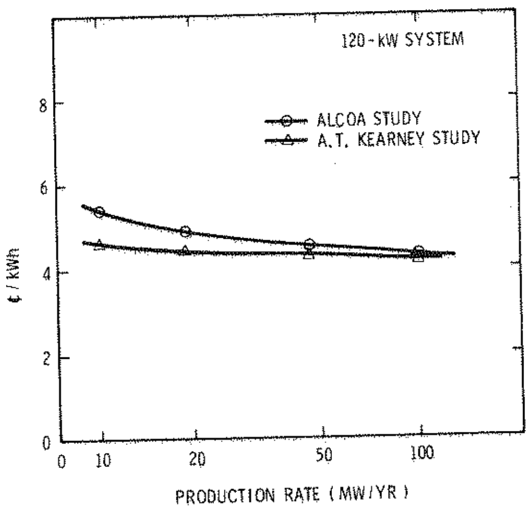


Figure 3.4 - Effect of Production Rate on Cost of Energy for the 120 kW Point Design

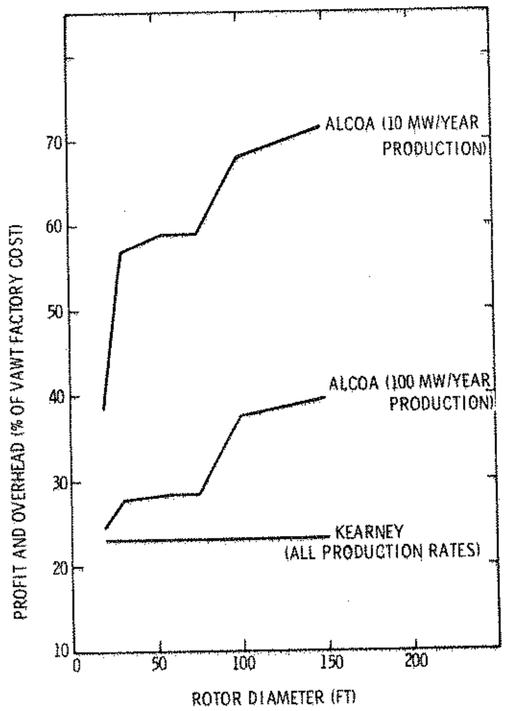


Figure 3.5 - Profit and Overhead Percentages Used by Kearney and Alcoa

summarizes the business related costs in the consultants' scenarios. While the contribution to overhead and profit is a constant 24% of the direct production cost in the Kearney VAWT scenario, the Alcoa scenario reflects a decreasing contribution margin as unit production volume increases.

The results in Fig. 3.4 are conservative because there is no accounting for cost reduction due to changes in design that would certainly occur as a result of production experience in any real manufacturing business. Effects of such design changes are not easily quantified, but their potential for substantial cost reduction is clear.

3.3 Identification of Cost Drivers

Figures 3.6 and 3.7 show the percentage of total hardware costs devoted to each major subsystem for the 100 MW/yr production case.* Comparing these two figures indicates that the Kearney and Alcoa studies are in good agreement regarding cost percentages.

It is difficult to discuss trends in Figs. 3.6 and 3.7 because the data points cannot be connected with smooth curves. The lack of smoothness in percentages is primarily due to electrical system specifications (such as voltage output and the use or nonuse of reduced voltage starters) that change from one point design to the next. Discrete changes in manufacturing methods and variations in the suitability of shelf components also produce anomalies in the percentage curves.

It is clear, however, that the hardware costs are generally driven (in descending order) by the rotor (blades and tower), the drive train (primarily the speed-increasing gearbox), the electrical system (generator and controls), and the tiedowns. The first two items on this list in most cases make up 70-80% of the total hardware cost.

3.4 Preproduction Prototype Costs

The contractors were also asked to consider the installed cost of one or four preproduction prototype units for each point design. The Kearney study uses the same business scenario for the prototypes as for the production case; i.e., a central firm managing the project with all fabrication handled by specialty subcontractors. Alcoa also uses this scenario for prototype costs. The Alcoa study presents results only for first-unit costs, the fourth-unit case being omitted.

*The results in Figs. 3.6 and 3.7 are derived from revised Kearney and Alcoa data as summarized in Tables 4.3 and 4.4. The nature and magnitude of the revisions are discussed in Section 4.

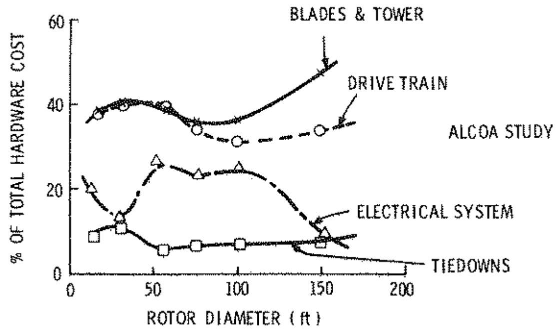


Figure 3.6 - Alcoa Component Cost Percentages

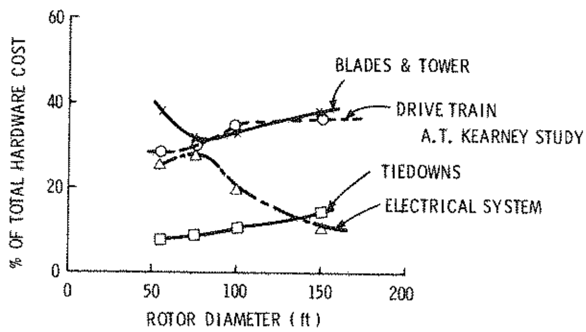


Figure 3.7 - Kearney Component Cost Percentages

Table 3.5 summarizes total system installed costs for the prototypes, costs that are substantially larger than the production unit costs presented in Section 3.2. The sources of increased costs in the Kearney study are primarily tooling expenses and increased contingencies on installation and component costs. The overhead and profit percentages for the firm managing the prototype construction are assumed to be the same as for VAWT, Inc. In the Alcoa study, increased tooling costs are accounted for along with a 20% contingency on the total system cost. The management firm's overhead and profit is taken to be 30% of total installed cost. Alcoa also adds on engineering costs ranging from $50,000 for a 10 kW system to $85,000 for a 1600 kW system to account for minor engineering required during prototype construction.

Table 3.5
Preproduction Prototype Costs ($)

	System Size (kW)					
	10	30	120	200	500	1600
Alcoa, 1st Unit	77,150	97,930	193,490	289,540	517,250	1,263,230
A. T. Kearney, 1st Unit	---	---	226,236	375,279	600,661	1,425,818
A. T. Kearney, 4th Unit	---	---	152,384	248,814	403,236	989,343

Results for both studies on prototype costs assume that the designs are complete and ready for construction with no requirements for substantial engineering time. Also, the management firm overseeing the construction is assumed to be a relatively low-overhead operation. Any comparison of results in Table 3.5 with actual prototype procurements should consider the applicability of these particular assumptions.

4. Analysis of Cost Derivations

Tables 3.2 and 3.3 summarize the unmodified results of the two cost studies. Differences between Alcoa and Kearney cost estimates are present for all subsystems. Because these divergences are important indicators of the uncertainty of each cost estimate, analyzing them can isolate critical assumptions about the cost and design of VAWTs.

The two studies must be examined for cost derivations that may be incorrect before significant uncertainties can be identified. Several important inconsistencies in the unpublished backup data to the cost studies were found and are discussed in the following two paragraphs.

The Kearney study assumes that VAWT, Inc. overhead and profit is 21% of the cost of each purchased turbine component; however, many components are not loaded correctly according to this assumption. The most notable are the 120 kW blade, the three smaller sized generators (120, 200, and 500 kW) and certain other electrical parts, the 1600 kW generator, all transmissions, and all tower tubes. These components are given combined overhead and profit loadings of 2, 43, 7, 11, and 43%, respectively. Costs for the 1600 kW blade at the 100 MW/yr production rate are 22% low due to an error in addition. The cost quote for the Kearney 120 and 200 kW transmission is about 20% low because it is for a horizontal rather than vertical mount as required by the design. Kearney mistook a quote for three tiedown cables as a quote for one cable and so based their tiedown estimates on a cost per pound that is three times too high. Kearney specifies a 4180 V electrical generator to meet the requirements of the 1600 kW design, but the price quoted is for a 480 V generator costing 40% less.

The Alcoa report does not include the cost of a hydraulic power unit to energize the hydraulic brakes. Alcoa electrical systems for the 200 and 500 kW units produce a 480 V output, while the point design specifications call for 4160 V.

Tables 4.1 and 4.2 are revised summaries of the cost studies that correct for the inconsistencies just mentioned. Assuming Tables 4.1 and 4.2 fairly represent the intentions of the consultants, the remaining differences in cost are due to dissimilar assumptions and approximations made by the consultants.

One of the most significant assumptions is that Alcoa believed the 500 and 1600 kW estimates should have contingencies relatively higher than those for the smaller systems. As described in Section 3, Alcoa estimates are based on a compilation of quotes from vendors. Details of this transformation are not documented, but a comparison of baseline quotes with final Alcoa results shows that Alcoa was more

Table 4.1

Revised Component Cost Summary
10 MW/yr Production (K $)

Nominal System Size (kW)	Source	Blades	Tower	Drive	Tiedown	Electrical	Delivered Sales Price	Foundation	Erection	Total
10	Alcoa	1.0	2.8	3.0	0.6	2.0	9.4	1.3	1.5	12.2
30	Alcoa	3.2	5.0	5.0	1.3	2.5	17.0	2.4	1.6	21.0
120	Kearney	8.9	12.8	15.9	4.6	9.9	52.1	10.9	10.5	73.5
	Alcoa	18.4	9.4	21.1	2.9	9.6	61.4	16.0	14.0	91.4
200	Kearney	16.1	21.2	34.0	10.6	29.0	110.9	11.0	13.4	135.3
	Alcoa	31.4	25.5	33.4	6.7	23.5	120.5	24.5	20.5	165.5
500	Kearney	36.2	42.3	79.5	21.3	37.3	216.6	14.2	29.2	264.6
	Alcoa	59.1	80.0	71.0	17.5	76.3	303.9	45.0	37.0	385.9
1600	Kearney	185.6	106.5	205.0	69.1	55.2	621.4	33.2	49.3	703.9
	Alcoa	234.8	232.4	219.8	48.4	89.6	825.0	133.0	67.0	1025.0

Table 4.2

Revised Component Cost Summary
100 MW/yr Production (K $)

Nominal System Size (kW)	Source	Blades	Tower	Drive	Tiedown	Electrical	Delivered Sales Price	Foundation	Erection	Total
10	Alcoa	.7	1.9	2.6	.6	1.4	7.3	.9	1.1	9.3
30	Alcoa	1.8	2.5	4.3	1.3	1.4	11.3	2.1	1.4	14.8
120	Kearney	7.7	11.0	14.0	4.1	8.9	45.7	10.1	9.7	65.5
	Alcoa	9.4	4.5	18.5	2.5	6.1	41.0	16.0	14.0	71.0
200	Kearney	13.5	18.8	30.5	9.8	26.2	98.8	10.1	12.4	121.3
	Alcoa	16.7	13.5	28.3	6.1	19.3	83.9	24.5	20.5	128.9
500	Kearney	26.4	37.1	70.4	19.7	33.6	187.2	12.8	27.0	227.0
	Alcoa	34.1	41.0	64.1	14.9	52.3	206.4	45.0	37.0	288.4
1600	Kearney	117.5	89.4	191.8	64.7	52.0	515.4	30.6	45.0	591.0
	Alcoa	130.7	121.6	176.8	42.2	47.7	519.0	133.0	67.0	719.0

conservative in their estimates for the 500 and 1600 kW systems. The size of this contingency varies between subsystems, being minimal for standard components like those found in the drive train and tiedown subsystems. The size of the contingency allowance is also related to production rates. At a production rate of 10 MW/yr, the 500 kW sales price includes an average 20% contingency allowance, and the 1600 kW price includes a 33% allowance. At 100 MW/yr, these numbers decline to 15 and 20%, respectively, indicating that contingencies unique to the larger systems may be reduced with increased volume of production.

Cost improvement through greater volume is an important assumption found in the studies. Table 4.3 shows the amount of cost improvement arising from an increase in

Table 4.3

Expected Cost Improvement Through Increased Production
100 MW/yr Cost as a Fraction of 10 MW/yr Cost

	System Size (kW)			
	120	200	500	1600
Kearney	.877	.891	.864	.829
Production Range	83-830	50-500	20-200	6-62
Alcoa	.668	.696	.679	.629
Production Range	84-1285	46-704	18-270	6-99

annual production from 10 to approximately 100 MW. Alcoa assumes a faster rate of improvement than Kearney and both studies show a faster rate in the larger size turbines. The former tendency reflects Alcoa's vertical-integration strategy, while the latter is a logical outcome of the fact that costs for larger units are more heavily influenced by nonstandard parts with a correspondingly greater potential for learning.

The remaining assumptions of importance deal with specific components. Foundation costs differ, principally because Alcoa assumed installed concrete costs of \$206 to \$266/yd^3 while Kearney used costs of \$66 to \$109. It should be mentioned that foundation volumes have been the subject of a major reduction effort since the consultants' studies were completed so that future studies should reflect significantly decreased foundation costs.

Erection costs vary due to differing assumptions as to the total labor hours required. Labor, machinery, and overhead rates are nearly identical between the studies.

The chief variation in blade cost is that Kearney used weights which are 75, 90, and 75% of the point design weights for their 120, 200, and 500 kW blade designs, respectively. The basis for this reduction is unknown. In addition, Kearney uses a low-cost per pound extrusion for the blade clamps while Alcoa uses a more expensive casting.

Tiedown costs for Alcoa are lower by about 30% than they are for Kearney, mainly because Alcoa determined that only one hydraulic cable tensioner is required while the point design originally called for three.

The final important difference involves Alcoa's 200 kW electrical costs that reflect use of a direct full voltage starter, while Kearney uses a reduced voltage starter that adds about $15,000 to their cost. Both studies use full voltage starters on smaller (less than 200 kW) units and reduced voltage starters on the remaining larger units. Reduced voltage starting decreases the power transients fed into the utility power grid and lowers stress levels on the drive system.

It is not within the scope of this study to determine the appropriateness of the major assumptions just mentioned. The assumptions are mentioned in order to show the type of uncertainties which affect the accuracy of the study results.

5. Review of the Economic Optimization Model

The VAWT economic optimization model described in Volume II of this publication is at an evolutionary state designated Version 16. The optimization model is the primary basis at Sandia for selecting optimum specifications for VAWT systems. It is important, therefore, that the model be confirmed or readjusted in accordance with the results of the detailed point design analyses.

In the first half of this section, the point design cost estimates of Version 16 will be compared with the estimates of Alcoa and A. T. Kearney. Tabulated values for these estimates are shown in Tables 5.1 and 4.1, respectively.

The second half of this section assesses the sensitivity of the optimization routine to another possible set of cost assumptions. Version 16 is modified to incorporate most of the consultants' cost relationships and a new set of optimization curves are generated for comparison with the original Version 16 curves.

5.1 Comparison of the Optimization Model with the Consultants' Results

Version 16 is an approximate scheme designed primarily to predict relative design optima, identify cost trends, and to estimate the absolute cost of VAWT systems. However, Version 16 should not be viewed as being as comprehensive as the cost formulations of Alcoa and Kearney. It has been expedient in Version 16 to neglect the cost of many minor components and business oriented overhead costs. Furthermore, Version 16 assumes a "mature" production rate which is not based on any set rule. As a result of these estimating liberties, the focus of the ensuing comparison of Version 16 with the consultants' results will be on cost trend differences and very large (above 20%) absolute cost differences.

Figure 5.1 shows total system energy costs as found by Alcoa, A. T. Kearney, and Version 16. Similar trends in cost versus size are apparent although Version 16 underpredicts the Alcoa and A. T. Kearney studies in absolute cost. This underprediction is due primarily to the exclusion of both business-oriented indirect costs and many small components in Version 16.

Figure 5.2 shows blade costs trending toward a minimum in the 55 to 100 foot rotor range. The differences in Version 16 blade costs relative to the consultants involve blade weight, extrusion capabilities, and blade clamps. Alcoa reduced the internal webs in the 18 and 30 foot rotor blades and so cut these weights by 15-20% while keeping blade strength at an acceptable level. A. T. Kearney reduced blade weights for the 55, 75, and 100 foot rotors by 25, 10, and 25%, respectively, however, no rationale for the reduction is available. Both Alcoa and Kearney assumed extrusion of the 75 foot rotor blade as a single section of 29" chord was possible.

Table 5.1

Predicted Component Costs for the Point Designs

Nominal Rating (kW)	10	30	120	200	500	1600
Component Costs ($):						
Blades	1180	3110	9120	21,300	47,200	160,000
Tower	635	1910	8260	22,500	46,500	176,000
Tiedowns	262	883	4290	11,700	23,800	78,500
Transmission	399	1570	8020	17,200	41,200	116,000
Generator and Controls	2650 (460 V)	3920 (460 V)	9180 (460 V)	22,600 (4160 V)	45,300 (4160 V)	67,300 (4160 V)
Field Erection and Foundations	1260	4630	15,100	26,400	44,300	119,000
TOTAL	6380	16,000	54,000	122,000	248,000	717,000
¢/kWh @ 15% Annual Charge	6.97	4.65	3.30	3.72	3.50	3.65

All Costs From Version 16 of the Optimization Model

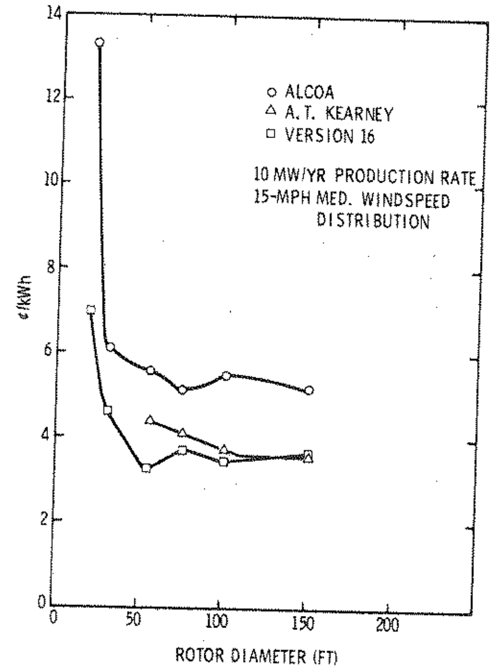


Figure 5.1 - Total System Energy Cost vs System Size

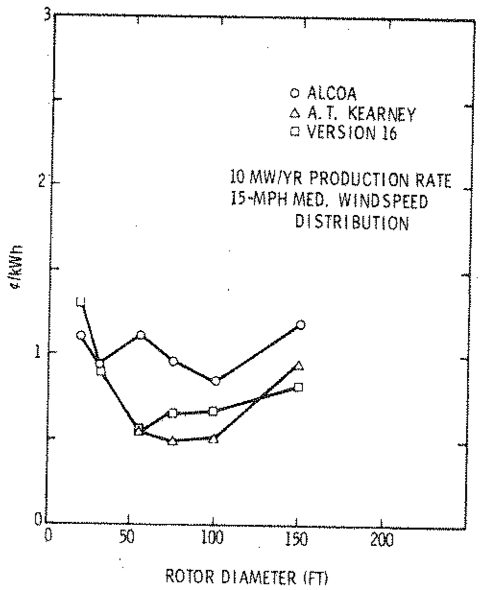


Figure 5.2 - Blade Cost Projections

Version 16 limited extrusion size to the 24" chord of the 55 foot rotor and so the blade for the 75 foot rotor was welded from two extrusions at greater expense. 24" is the maximum size extrusion press in the USA, however, a process using a flared die will probably be able to extend the dimension to 29". Alcoa costs are relatively highest over the entire range because about 35% of their total blade cost is generated by a set of cast aluminum blade clamps. A. T. Kearney blade clamps are extruded at a lower cost than casting and contribute about 20% to the blade cost. Version 16 neglected blade clamp costs.

Figure 5.3 shows tower costs, where the major differences involve wall thickness,

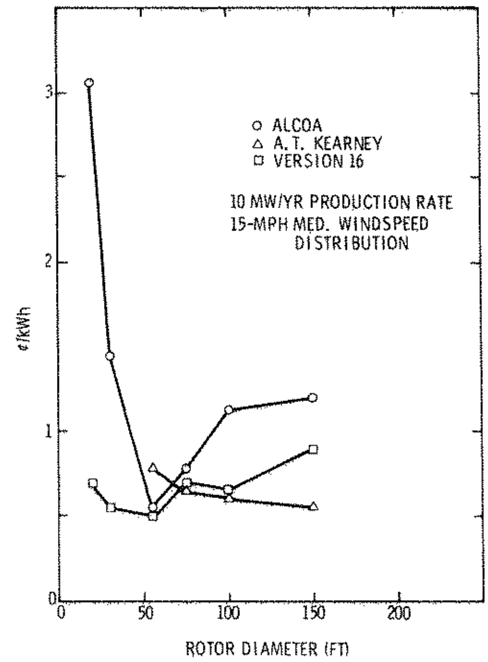


Figure 5.3 - Tower Cost Estimates

quantity discounts, and contingency planning. Version 16 minimizes tower weight using a large diameter, thin-walled tube while the consultants chose to use heavier standard wall thickness tubes. These approaches yielded comparable tube costs except for the 150 foot design which cost 40% less in the standard thickness estimated. The high values for the Alcoa estimates at low rotor diameters are believed to arise from the use of quotes for quantities of only 25. Alcoa found that fabricators would not quote on the larger quantities specified for the smaller units but significant cost economies seem likely. For the 100 and 150 foot rotor designs, Alcoa is believed to have increased initial tower estimates as a contingency against the greater uncertainty of such large designs.

Figure 5.4 indicates tiedown costs are in fair agreement. Version 16 neglected

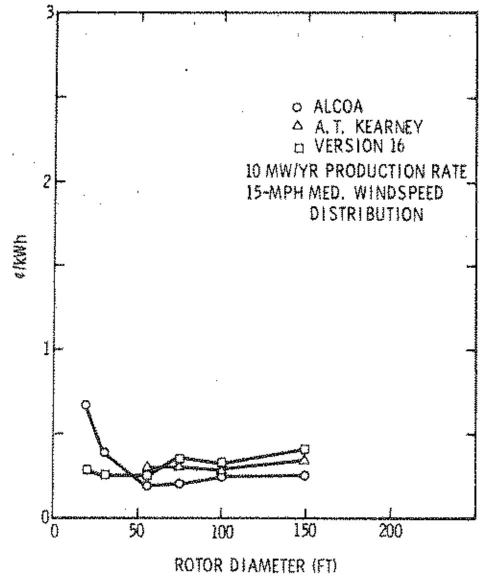


Figure 5.4 - Tiedown System Cost Comparisons

cable tensioners and used a cable socket cost which was scaled from the 55 foot rotor design. Tensioners and fixed socket costs are quite negligible for the large designs but are significant to the tiedown costs of the 18 and 30 foot rotor machines, where Version 16 appears to underestimate.

Figure 5.5 shows the drive train costs. Version 16 neglected flexible coupling costs, brake costs, and rotor support costs which are significant for all sizes but are especially important for small turbines. In addition, the transmission costs in Version 16 are less than in the consultants' studies, probably as a result of the use of 2 year old data in the Version 16 transmission model.

Figure 5.6 shows the electrical system costs. No significant cost differences between Version 16 and the consultants' studies were identified.

The site related costs of Fig. 5.7 consist of foundation and erection costs. These two costs are difficult to accurately assess. Version 16 assumes the foundations can be constructed with roughly one half as much concrete as used in the Alcoa and A. T. Kearney studies. Version 16 and A. T. Kearney use about $100 per cubic yard as a poured concrete cost while Alcoa uses twice this amount. The Version 16 erection labor hours are slightly above Alcoa and about twice the A. T. Kearney amount. The dip in the Alcoa cost curve for the 18 and 30 foot rotor models is primarily due to the substitution of less expensive rural labor for small machine markets in the Alcoa business scenario.

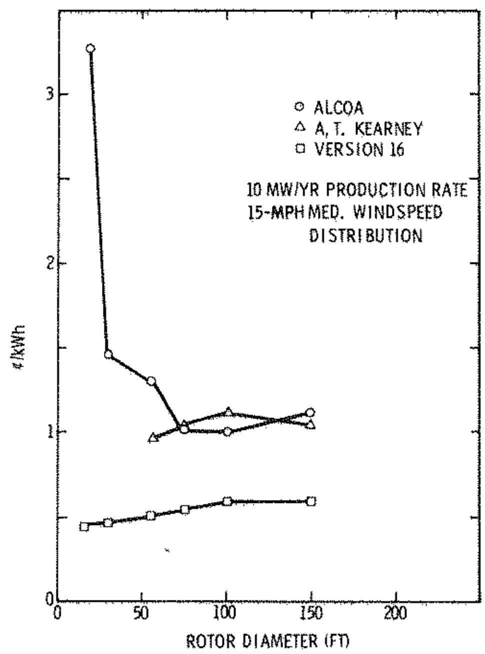


Figure 5.5 - Drive Train (Transmission and Couplings) Cost Projection

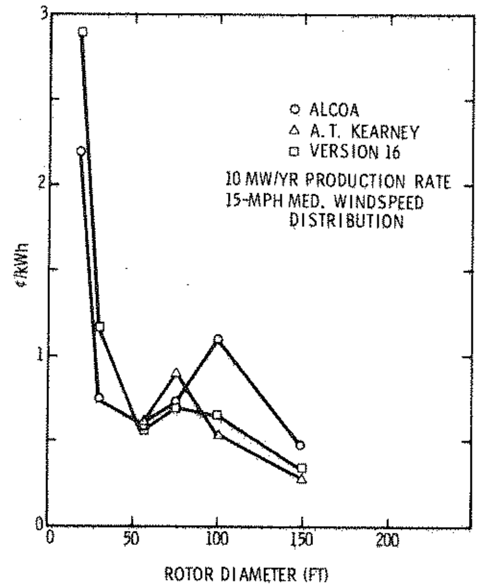


Figure 5.6 - Electrical Controls Cost Projections

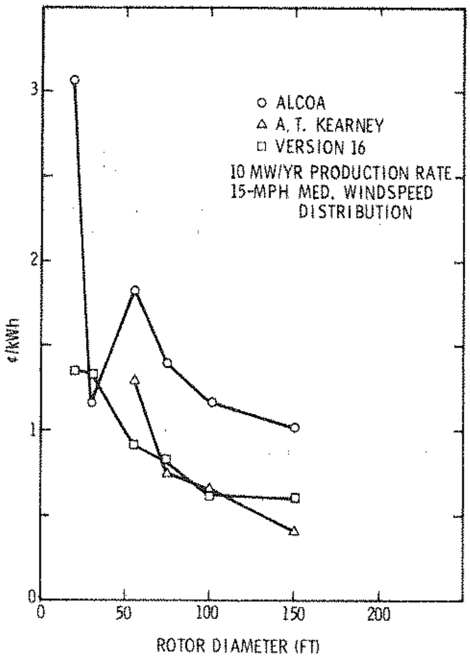


Figure 5.7 - Assembly and Installation Cost Estimates

5.2 Economic Optimization Using a Revised Cost Model

The cost findings of the consultants have been selectively incorporated into a revision of the Version 16 cost model. The revision is at an uncertain state of development and will not represent an improvement over Version 16 without further work. The revision is presented here to assess the sensitivity of design optimization processes to the type of changes which might be made in the Version 16 cost model. In general, the revision was based on the Alcoa study cost data, although Kearney estimates are used for the brake power unit and blade clamps and the foundation costs are from an estimate made by the Civil Engineering Research Facility (CERF) of the University of New Mexico.* A brief summary of these changes is presented in Table 5.2.

Figure 5.8 shows energy cost for both Version 16 and the revised cost model. These plots represent optimum combinations of solidity and operating speed with the height-to-diameter ratio fixed at 1.5. The curves indicate similar trends including increases at 60 ft. and 120 ft. rotor sizes caused by the addition of a second or third blade extrusion upon reaching 24" press limitations. If a 29" extrusion proves

*SAND78-7046, "A Study of Foundation/Anchor Requirements for Prototype Vertical Axis Wind Turbines," H. E. Auld and P. F. Lodde.

Table 5.2

Revised Cost Model Changes from Version 16
(Listed in Approximate Order of Magnitude)

1. Foundation costs modified to reflect CERF study
2. Cost/lb for aluminum extrusion modified to reflect chord dimension
3. Tower resonance in torsion condition relaxed
4. Transmission costs increased
5. Rotor support included
6. Low speed coupling included
7. Clutch and brake included
8. Cable tensioner included
9. Rotor shaft to bearing transition weight modified
10. Flange costs included
11. Rotor tube cost/lb reduced
12. Cable cost divided into cable and terminations
13. Extruded aluminum blade clamps included
14. Generator costs modified to reflect Lincoln prices below 200 Hp
15. Lightning arrestor included
16. Tiedown cables sized in 1/8" increments
17. Bearing costs increased
18. Rotor cable connector included
19. Tiedown fittings included
20. Rotor tube thickened around blade fitting
21. Webbing on small blades decreased
22. Minimum ground clearance equation modified
23. High speed coupling costs included

feasible, these dips will move out to approximately 70 ft. and 140 ft. If the second dip moved out to 140 ft., the cost would resemble the Alcoa cost curve of Fig. 5.1 which appears to be decreasing steadily in cost versus size at 150 ft. but may similarly be about to rise. As with Version 16, the revised cost model indicates that cost/kWh is rising at the 200 ft. rotor diameter.

The optimization of turbine design (see Section 4.2 of Volume II) is affected very little by the revised cost inputs. Figures 5.9, 5.10, and 5.11 show curves of cost/kWh versus rpm, solidity, and height/diameter. For each figure, the revised cost model gives higher absolute cost, but the optimum value of each parameter remains nearly the same as for Version 16.

Future work may change the cost structure of Darrieus-type turbines so as to significantly change the optimum design parameters. At the present, however, the

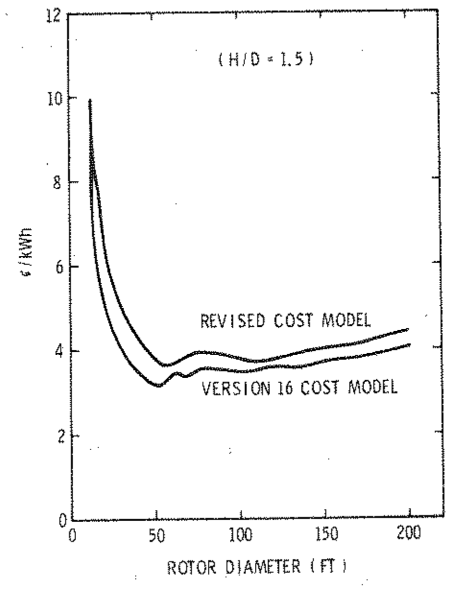


Figure 5.8 - Predicted Energy Cost of Optimized Systems

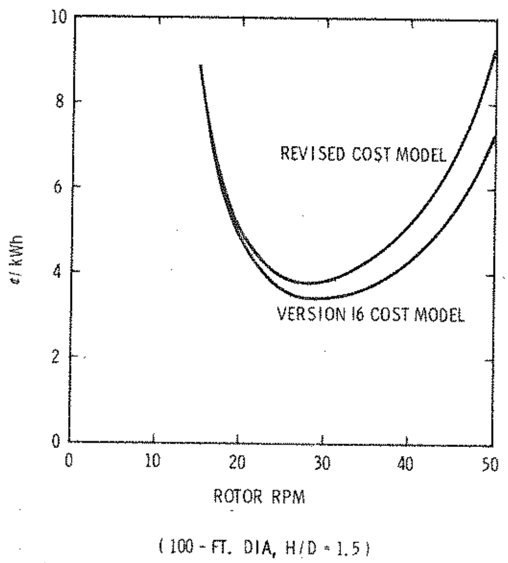


Figure 5.9 - Optimum Rotor rpm for Version 16 and the Revised Cost Model

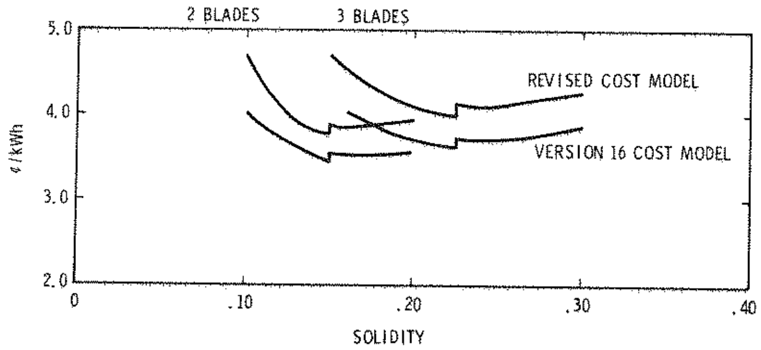


Figure 5.10 - Rotor Solidity Optimization for Version 16 and the Revised Cost Model

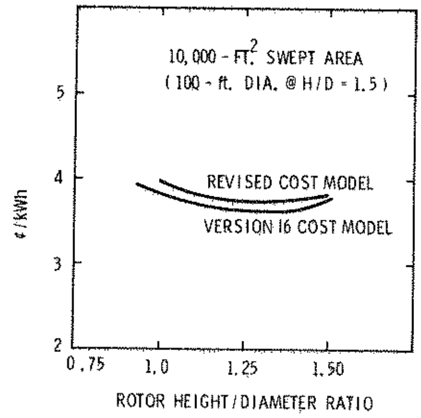


Figure 5.11 - Effect of H/D Variation on the Cost of Energy

findings of Alcoa and A. T. Kearney appear to have confirmed the optimum parameters as determined by Version 16. The consultants' work should be of great value in broadening the scope of the economic model in the future.

6. The Influence of Automatic Controls and Operation and Maintenance (O&M) on System Cost of Energy

The six point designs analyzed in this study do not include any automatic control equipment which may be required for unattended operations of the systems. Also, the cost of energy calculations in Sections 3 and 4 assume that the annual operation and maintenance costs are imbedded in the annual charge rate, taken to be 15% of the initial system cost. To put this study in common with other DOE-sponsored studies on alternate energy system economics, this section will consider the effect of automatic controls and itemized O&M on the cost of energy.

6.1 Capital Cost of Automatic Controls

The six point designs do include, under the name of "electrical controls" all the contactors, transformers, circuit breakers, and low-voltage control panels for manual push-button operation of the system. The automatic controls are an additional feature required to operate the panels without attendants.

The primary function of the automatic controls is to initiate starting or stopping of the rotor based on local wind conditions and to curtail operations if critical faults are detected. Certain additional functions may be desired for the larger, utility-operated systems. These functions include: monitoring and storage of limited statistics on site wind characteristics, energy output, and system state-of-health parameters; and the ability to transfer turbine control and operational data to a central site at a location far from the turbine. It is assumed that these expanded capabilities are appropriate for the three largest point designs (200, 500, and 1600 kW). The smaller machines' (10, 30, and 120 kW) automatic controls will only start, stop, and protect the system.

For the purpose of estimating costs, it is assumed that the automatic controls will be microprocessor-based and each turbine will have its own independent control system. These assumptions should be carefully acknowledged when examining very small systems (less than 10 kW), or wind turbine "farms" with many rotors in close proximity. In the former case, simple electro-mechanical controls (such as centrifugal switches, relays, thermal overloads, etc.) may offer a less expensive solution than microprocessors. In the latter case, many turbines could conceivably be controlled by a single microprocessor-based system.

The actual hardware required to control small systems (Level I) and large systems (Level II) is given in Tables 6.1 and 6.2. The prices shown are approximate list prices obtained from catalogs. The cost of either the Level I or Level II control systems is assumed to be independent of the point design size. This is because

Table 6.1

Level I Control Hardware

Component and Function	Approximate List Price
Microprocessor (PROM only)	
- Read anemometer pulses, digital fault detectors, start or stop rotor	$ 250
5 Channel Relay Matrix	
- Provide interface between microprocessor and system electrical control switches to start motor, release brakes, etc.	400
Digital (Switches or Pulse Stream) Transducers	
- Anemometers (2)	200
- Mechanical tachometer	200
- Thermal switches (2)	50
- Brake system pressure switch	50
- Vibration sensing switches (2)	400
Emergency Battery	300
TOTAL	1850

Table 6.2

Level II Control Hardware

Component and Function	Approximate List Price
Microprocessor (4K or greater RAM with PROM)	
- Read anemometry, fault detectors, decide to stop or start rotor - Store statistical data from anemometers, power meter, and fault detectors for transmission to central site	$4500
10 Channel Relay Matrix	
- Provide interface between microprocessor and system electrical control switches to start motor, release brakes, etc.	600
8 Channel A/D Converter	
- Convert analog transducer data for microprocessor analysis	500
Telephone Modem	
- Provide link for central site communication	400
Analog Transducers with Conditioning Equipment	
- Anemometers (2)	200
- Power meter	400
- Mechanical tachometer	200
- Thermocouples (2)	200
- Brake system pressure switch	50
- Vibration sensing switches (2)	400
Emergency Battery	
- For short-term emergency power	300
	7750

there are no obvious changes required in the hardware based on the physical size of the turbine.

6.2 Annual O&M Costs

The estimated annual O&M costs expected for the six point designs are summarized in Table 6.3. These results are derived based upon the examples in Volume III.

Table 6.3

Annual Maintenance and Operation Costs

	10 kW	30 kW	120 kW	200 kW	500 kW	1600 kW
Maintenance and Inspection	$100	$150	$200	$ 400	$1000	$2000
Replacement	18	30	140	250	580	1300
Operation	433	433	433	433	433	433
TOTAL	551	613	773	1083	2013	3733
Levelized Total (2.0 x)	1102	1226	1546	2166	4026	7466

The annual cost estimates are intended to apply for mature production units only. Naturally, prototypes and early production units will require substantially greater O&M costs.

The dispatching cost is particularly dominant on the two smallest point designs (10 and 30 kW). It is conceivable that this cost may not be accountable if such units are placed on a farm and dispatched by the owner. More generally, however, the dispatching effort will require a real out-of-pocket expense, and therefore it is included even for the smallest systems.

6.3 Cost of Energy Modification for Automatic Controls and O&M

The cost of energy (COE) is calculated according to the formula:

COE = (ACR x System Cost + Levelized O&M)/(Annual System Energy x Availability)

The ACR is the annual charge rate for the initial capital investment, and is assumed to be 18%. The system cost is from Tables 4.1 and 4.2, with the controls cost of Tables 6.1 and 6.2 added. The automatic controls were increased in cost by 20% from Tables 6.1 and 6.2 to account for VAWT, Inc. handling. The O&M costs from Table 6.3 are levelized by a factor of two to account for inflation over the life of the systems. The availability factor is assumed to be 90%.

The COE resulting from these assumptions is shown in Fig. 6.1 for the 100 MW/yr

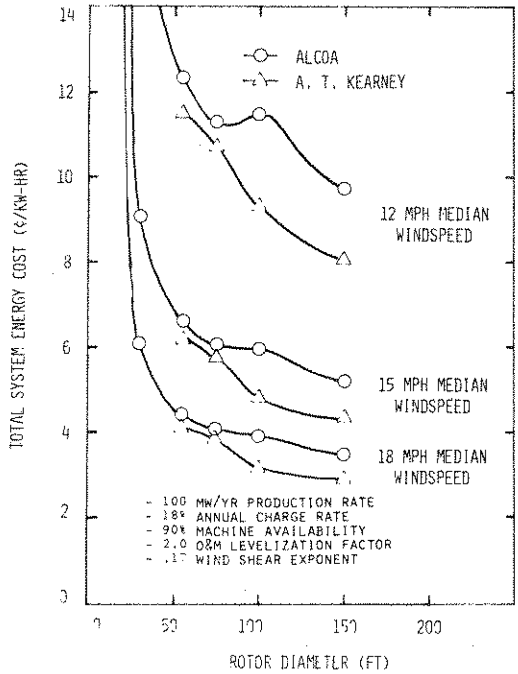


Figure 6.1 - Cost of Energy with Revised Formula

production rate. The most notable qualitative difference in these results relative to Figs. 3.2 and 3.3 is a stronger tendency to favor the larger systems. This is because O&M costs and automatic control system costs have components which are essentially independent of system size. These fixed-cost components have an increasing impact as system size and initial cost decrease.

APPENDIX A

Narrative description of the point designs supplied to the consultants on April 1, 1978.

NOTES: Design drawings are cataloged in Volume III of this study. The main narrative concerns the 200, 500, and 1600 kW point designs. A supplementary narrative is attached describing the 120 kW system.

The 10 and 30 kW systems are not discussed because the design of these smaller units was managed by Alcoa Laboratories.

Introduction

There have been three point designs of Darrieus vertical axis wind turbine systems completed by Sandia Laboratories. These designs are to be evaluated by outside consultants to determine the costs of fabricating, transporting, erecting, and marketing these systems on a production basis.

All three designs are relatively large units with centerline diameters of 75, 100, and 150 ft., respectively. The system output is AC electrical power. This is achieved by coupling an induction or synchronous generator mechanically to the rotor and electrically to a utility line. The resulting system operates at constant rpm, regulated by the utility line frequency.

The three systems, in order of increasing size, are referred to as the "200", "500", and "1600" kW systems. These names are only approximate measures of the size, and do not necessarily coincide with the actual nameplate ratings on the generators.

The mechanical design features are shown on the enclosed set of mechanical drawings. These drawings are supplemented by brief narratives on fabrication and assembly procedures to be used for the various subsystems.

Virtually all aspects of these designs should be considered as flexible baselines. If design or fabrication changes are seen by the consultants as potentially leading to significant cost reduction, Sandia Laboratories should be informed. If these changes do not unduly compromise the operational capabilities of the systems, they may be incorporated.

The level of detail in the design is intended to be adequate to make a reasonable assessment of the costs. If, in the judgement of the consultants, more detail is required on certain subsystems, Sandia should be contacted and an attempt will be made to improve the design definition.

Point Design Drawings

Number		Description
	200 kW	
S25325 #1		Transmission, Braking System, Generator Differential
S25325 #2		Universal Joint, Lower Tower Details, Lower Blade Attachment, Tower Joint
S25325 #3		Upper Tiedown Attachments, Upper Tower Bearing, Upper Blade Attachment, Lightning Mast
S25325 #4		Tiedown Footings
S25325 #5		Tiedown Tensioning Device and Footing Mount Hardware
S25325 #6		Overall Turbine Layout and Blade Geometry
	500 kW	
S24633 #1		Transmission, Braking System, Generator, Differential
S24633 #2		Universal Joint, Lower Tower Details, Lower Blade Attachment, Tower Joint
S24633 #3		Upper Tiedown Attachments, Upper Tower Bearings, Upper Blade Attachment, Lightning Mast
S24633 #4		Overall Turbine Layout and Blade Geometry
S24633 #5		Tiedown Tensioning Device and Footing Mount Hardware
S24633 #6		Blade/Tower Attachment Fitting
S24633 #7		Blade/Joint (Transverse)
S24633 #8		Tiedown Footing
S25070 #1		Erection Scheme, Secondary
S25070 #2		Erection Scheme, Primary

Number		Description
	1600 kW	
S25603 #1		Transmission Layout, Starting Clutch, Brake System
S25603 #2		Lower Blade Attachment Fittings, Universal Joint, Tower Joints
S25603 #3		Upper Blade Attachment Fittings, Upper Tiedown Connection, Lightning Rod
S25603 #4		Blade Attachment Fitting Detail
S25603 #5		Blade Joint (Transverse)
S25603 #6		Tiedown Tensioning Device and Footing Mount Hardware
S25603 #7		Tiedown Footing
S25603 #8		Overall Turbine Layout

Blades

The blade is defined as all portions of the aerodynamic section joining the upper and lower attachment points on the tower, and including all attachment fittings and joints required for the field assembly of the blade. Factory operations on the blades consist of fabricating and attaching any necessary end fittings, bending the blade, checking tolerances, and packaging for shipment. Field operations will be limited to the assembly of blade sections and their connection to the tower mounting flanges.

The overall geometry of each blade for all three designs consists of two straight sections joined to a curved portion which is a sector of a circle (S22633 #4). The number of joints along the blade (referred to as "transverse joints") varies for each point design, and is governed by a desire to make each blade segment deliverable to the site by conventional overland trucking.

The basic blade sections are assumed to be aluminum extrusions. The material is 6063 aluminum with temper appropriate to an air quench. No additional heat treatment is anticipated.

Restrictions on the maximum throat size of extrusion presses available in the United States has led to the use of multiple piece extrusions on the 500 and 1600 kW designs (S24633 #8 and S25603 #2, respectively). These sections are intended to be joined (referred to as "longitudinal joints") as straight extrusions prior to any bending operation. Spot welds (two welds per chord length) will be used to prevent longitudinal slipping of the joint.

The curved portion of the blade will be formed either by incremental three-point bending, rolling, or stretch forming.

The transverse joints for all three point designs are similar to the 1600 kW (S25603 #5) design. These joints are fabricated from extruded aluminum joint inserts which fit in the hollows in the blade cross section. These inserts will be attached to the blade using blind rivets through the outer skin of the blade. The holes required for the rivets should be drilled at the factory and the joint assembly completed in the field.

The blade attachment fitting which joins the blade to the tower (S25325 #3) on the 200 kW turbine is illustrative of all the designs. This differs from the transverse joints because of increased strength requirements and reduced aerodynamic constraints in the turbine hub area. The joint is effected in two stages to reduce stress concentrations in transferring load from the blade to the tower. The first stage is an enveloping clamp with its interior profiled to the blade contour. This clamp is bolted to the blade through the blade skin. This clamp may be made of steel or aluminum, and may be cast, forged, extruded, or machined, whichever is more economical. The second stage envelopes the first stage, and has a rectangular cross section. This section terminates at a flange which is bolted to a similar flange on the tower. The second stage should be made of steel and may be a weldament, if desired. The remainder of the joint past the flange should be considered as part of the tower, rather than the blade.

The assembled blade, when placed on a flat surface, leading edge down, should indicate deviations from the specified geometry less than 5% of the chord length. The blade chord line should be perpendicular to the flat surface within ± 2°. Surface finish of the blade should be within normal extrusion capabilities and practice.

Tower

The tower is defined as all portions of the turbine above the low speed transmission shaft, excluding the blades, blade attachment fittings, and the cable tiedowns with their terminations.

The tower design on the 500 kW system (S24633 #'s 2 and 3) is typical of all three point designs. The tower is assumed to be fabricated entirely of mild steel, with a 30 ksi yield stress.

The portion of the tower between the blade attachment points is a relatively large diameter, thin-walled tube. The tube is sectioned, with joining flanges for connecting adjacent sections. The thin-walled tube should be fabricated by rolling and welding steel sheet, as in culvert pipes. The joint flanges are attached to the thin-walled tubes by a continuous circumferential weld. These joint flanges should be fabricated by rolling and welding, casting or forging, whichever is more economical.

The blade is joined to the tower using a special thick-walled tower section at the attachment point. The blade mounting hardware and flanges are attached to this thick section. These special tower sections and the blade mounting hardware are to be welded into a single unit.

Most other joints in the tower are welded, unless indicated otherwise on the drawings. It is intended that all welds will be completed at the factory, with field operations limited to the bolting together of completed subassemblies.

A lower universal joint is specified on the drawings. This joint is incorporated to aid rotor erection and to prevent eccentricities in the tower from transmitting destructive moments to the transmission. The universal joint cage is welded from steel plate sections. The spider should be forged or cast, with machined ends for the universal joint bearings. The universal joint bearings are plain bushings.

The entire tower, excluding joining surfaces, should be painted with a finish appropriate for a 10 year cycle between repainting.

Machining operations on the tower should be limited to the universal joint, the joining flange faces, and drilling and tapping necessary screw joints.

Requirements on tolerances are limited to the assembled tower, and not individual components. For the assembled tower, indicated runout of the tower perpendicular to its centerline should not exceed 2% of the tower diameter. The upper bearing plate should be perpendicular to the tower axis within 1°. It is expected that such tolerances can be realized with limited tolerances on individual components by preassembling and shimming the tower assembly at the factory. The shimmed tower may then be indexed and disassembled for shipment and field erection.

Tiedowns

The tiedowns consist of the three tower support cables with terminations and the fabricated hardware used to attach the cable to the concrete footings.

The footing attachment hardware for the 500 kW design (S24633 #5) is representative of all three designs.

The cable will be tensioned periodically, to account for differential thermal expansion and cable creep. This tensioning will be accomplished using hydraulic jacks on the footing to relieve the load on the hex nut (item 25, S24633 #5). The hex nut may then be adjusted, using the small positioning motor, to another position. The hydraulic jacks will only be used for tensioning, and ordinarily the cable load will be carried by the hex nut.

All components of the footing attachment should be fabricated from 30 ksi steel. Machining operations should be limited to the cable attachment stud and the adjustment nut, which must both be threaded appropriately. The tiedown footing hardware should be painted with a 10 year cycle finish.

Transmission

The transmission consists of all portions of the turbine drive train between the lower coupling of the tower universal joint and the high speed input to the electrical generator. The transmission design for the 200, 500, and 1600 kW systems are shown on drawings S25325 #1, S24633 #1, and S25603 #1, respectively.

The principal element of the transmission is the gear type, enclosed speed increaser. In all three designs, a gearbox with a vertical slow speed input and horizontal high speed output shaft is used. It is intended to use a catalog item for this speed increaser, with some modifications to permit its use in this particular application. Table 1 summarizes the performance characteristics on the speed increaser for all three point designs. Also shown are Philadelphia Gear catalog numbers for gearboxes meeting these requirements. Any available gearbox is also acceptable, provided its specifications do not deviate from those in Table 1 by more than 10% and that the physical size and shape of the substitute can be reasonably accommodated by the existing system design.

Table 1

Drive Train Technical Summary - Point Designs
(All Results are for Sea Level Air Density)

	75 x 113	100 x 150	150 x 225
Selected Gear Ratio	44.9	57.7:1	88.0:1
Synchronous rpm	40.1	31.1	21.0
System Rating (kW) @ Synchronous rpm	225	530	1325
Maximum Average Torque, Low Speed Shaft @ Synchronous rpm	45,381	135,700	496,700
Selected Transmission	P.G., 14VB3, Triple Reduction	P.G., 18VBC, Triple Reduction	P.G., 22VB3, Triple Reduction
Torque Capacity of Selected Transmission, (ft-lb), Continuous Duty	51,250	159,833	475,416
Actual Service Factor for Selected Transmission	1.13	1.18	.96
Net Axial Transmission Load, Low Speed Shaft (lbs)	104,500	198,000	602,500

Most cataloged gearboxes will probably need modification to increase the thrust capacity so that the gearbox may provide the load path for rotor weight and tiedown reactions. This may require replacing the main lower support bearing on the low speed shaft of the speed increaser.

A mechanical starting differential is shown as a modification to the high speed end of the gearbox on the 200 and 500 kW designs. This differential is required <u>only</u> when the synchronous generator is used. In this configuration, the synchronous generator may be started without load by releasing the differential disc. This disc is then progressively stopped, providing a smooth application of torque to bring the high inertia turbine rotor up to speed. The starting differential is not required on the 200 and 500 kW machines using the induction motor/generator. This is because electrical controls may be used to provide sufficient starting torque through the motor.

The 1600 kW system cannot be started electrically with either the induction or synchronous generator. As a result, the mechanical clutching system (S25603 #1) is required for either the synchronous or induction generators. This starter uses a plate type clutch actuated by hydraulic cylinders. As this clutch is separate from the speed increaser, no modifications to the gearbox are required for starting.

All three designs use disc brakes for runaway protection and parking. For the 200 and 500 kW designs, the brake calipers are shelf items. This differs from the 1600 kW design, which uses specially fabricated calipers. A hydraulic system consists of a pressure accumulator, a hydraulic pump with fluid reservoir, and solenoid valves. Part numbers for this system, which should be the same for all three designs, are called out on S24633 #1.

The high speed shaftwork, couplings, and brake rotors are all assumed to be machined items. The entire drive train should be mounted directly on the concrete foundation at the turbine site. The alignment of the shaftwork should be by shimming the bases, to account for irregularities in the concrete surface.

Electrical System

The electrical system consists of a generator and all electrical controls required for system operations. The electrical systems for all three point designs begins at the input shaft of the generator and ends at an existing 4160 V, three phase utility line connection. In the case of the 200 and 500 kW systems, this connection will require a transformer, as the generator and controls are 480 V units. The 1600 kW system, alternatively, uses 4160 V electrical hardware and no transformer.

There are two options on the electrical system. Option 1 uses a synchronous generator, which will be started at full voltage under no load. Mechanical clutches will then be engaged to bring the turbine rotor up to speed. Option 2 uses an induction generator. On the 200 and 500 kW systems, this induction generator will be directly coupled to the rotor and will be started with a reduced voltage starter. On the 1600 kW system, the induction generator will be started with no load at full voltage, with subsequent mechanical clutching to start the rotor.

A summary of electrical system components and specifications follows. All of these components are intended to be purchased items. Reasonable deviation from the stated specification to permit using a particularly desirable cataloged component is acceptable.

The connection for the utility grid is assumed to occur outside the triangle formed by the tiedown footings. Provision should be made for buried cable from the edge of this triangle to the turbine center foundation. The transformer, if required, should be placed as close to the generator as possible, avoiding excessive lengths of high current lines.

A simple control panel, consisting of a start switch, stop switch, ammeter, and voltmeter shall be provided. Weatherproof enclosures should be provided for all electrical components which cannot be continuously exposed to severe weather conditions.

Turbine Foundation, Assembly, and Erection

It is assumed that the turbine site is accessible by roadway suitable for heavy trucks. The site is presumably level and excavations will be limited to the concrete foundations and underground wiring. The foundations should use materials and reinforcing bar density appropriate to standard engineering practice for building foundations.

The turbine components will be assembled as follows: the transmission and electrical unit will be attached to the center foundation and appropriate electrical connections made. The blades and tower will be assembled horizontally as a complete unit. The assembly is then erected, using the lower universal joint as a pivot. Following erection, the tiedown cables are attached to their footings, and the tensions adjusted. Alignment of the upper tower bearing relative to the transmission shaft will be checked with surveying equipment.

There are two erection schemes shown on the drawings (S25070 #1 and #2). Although these schemes are for the 500 kW turbine, the erection should be similar for all three point designs, with hardware scaled in proportion to tower length. Only the primary erection scheme (S25070 #2) need be considered in this study. This scheme requires a specially constructed erection rig with hydraulic jacks. The cost of this rig should <u>not</u> be added directly to the erection costs. Rather, it should be accounted for as plant equipment, to be used repeatedly in subsequent erections. The cost of any excavations or foundations required for the rig should be considered as part of the erection costs.

An 8' chain link fence with barbed wire on top and a lockable gate should surround the center foundation of the wind turbine. This fence should be as compact as

Electrical System Components

Option 1 - Synchronous Generator

	200 kW	500 kW	1600 kW
Generator Type	480 V Synchronous, 3ϕ	480 V Synchronous, 3ϕ	4160 V Synchronous, 3ϕ
Nameplate Rating	200 kW, 480 V	500 kW, 480 V	1500 kW, 4160 V
Starter	Full Voltage, 480 V, 400 Hp, with Mechanical Clutch	Full Voltage, 480 V, 600 Hp, with Mechanical Clutch	Full Voltage, 4160 V, 2500 Hp, with Mechanical Clutch
Transformer	225 KVA	500 KVA	N.R.
Circuit Breaker	480 V, 500 Amp	400 V, 1500 Amp	4160 V, 500 Amp

Option 2 - Induction Motor/Generator

	200 kW	500 kW	1600 kW
Generator Type	480 V Induction, 3ϕ	480 V Induction, 3ϕ	4160 V Induction, 3ϕ
Nameplate Rating	250 Hp (Motor), 480 V	600 Hp (Motor), 480 V	2000 Hp (Motor), 4160 V
Starter	400 Hp, 480 V Reduced Voltage Starter, Motor Direct Coupled to Turbine	600 Hp, 480 V Reduced Voltage Starter, Motor Direct Coupled to Turbine	2500 Hp Full Voltage, 4160 V with Mechanical Clutch
Transformer	300 KVA	750 KVA	N.R.
Circuit Breaker	480 V, 500 Amp	480 V, 1500 Amp	4160 V, 500 Amp

possible, while still permitting the movement of turbine components for maintenance operations.

Design Definition of the 120 kW Wind Turbine

The 120 kW turbine is to be similar to the 200, 500, and 1600 kW point designs except for the scale and in specifications on purchased items. The diameter of the 120 kW rotor is 55' and the height-to-diameter ratio is 1.5.

The blade section has a nominal 24" chord and is shown in Fig. 1. This blade section is intended to be extruded as a single piece. Multiple piece extrusions may be used if this is advantageous from a cost standpoint. For multiple piece extrusions, the blade design from the 500 kW turbine should be scaled down from the 43" chord to a 24" chord.

Virtually all fabricated components for the 120 kW turbine may be assumed to be scaled replicas of the 200 kW design, where the scaling ratio is 55/75. An exception to this rule applies to the blade joints and the tower attachment fitting. These components should be scaled in proportion to the blade chord, i.e., a scaling ratio of 24/29.

The number of transverse joints on the 120 kW machine should be two per blade, and be located at the junction between the circular and straight sections of the blade. The tower will only have one shipping joint, located halfway between the upper and lower blade attachment fittings.

The purchased hardware for the 120 kW design differs in specification from the other point designs. These specifications are given in Table 1. Note that a transformer is not required for the 120 kW system, and it is assumed that the utility connection is at 480 volts, rather than the 4160 volts for the other designs. Also, the 120 kW design will use the induction motor/generator exclusively. This precludes the option for the synchronous generator and starting differential used on the 200 kW design.

Table 1

Purchased Items - 120 kW Turbine

Gearbox	Philadelphia Gear 11VB3, 34.5:1, 165 Hp, 201,000 in-lbs torque capacity. Thrust capacity - 25,000 lbs, thrust requirement - 45,000 lbs
Starter Differential	N.R.
Brake Caliper (1)	Kelsey-Hayes, Model 2500H
Tiedown Cables (3)	1-5/16" diameter with sockets, 175' length
Tiedown Tensioning Hydraulic Cylinders	RCH 202, 20 T Enerpac
Upper Tower Bearing (1)	Rotek, series 3000 - A817P3D
Lightning Brush Assembly	Same as 200 kW
Induction Motor/Generator	150 Hp, Lincoln Electric, frame size 444T
Reduced Voltage Starter	150 Hp, 380-575 V
Circuit Breaker	600 V, 4000 amp, square D, catalog # LAE 36400
4160 - 480 V Transformer	N.R.
Synchronous Generator	N.R.

APPENDIX B - A. T. Kearney Final Report

CONTENTS

- OBJECTIVES, SCOPE, APPROACH
- PRODUCTION PLAN DESCRIPTION
- COST ESTIMATING PROCEDURES
- COST ESTIMATES
- FLOW PLAN (FOLDOUT)
- BACKUP DATA (UNDER SEPARATE COVER)

OBJECTIVES

- REASONABLE ESTIMATES OF VAWT COST TO CUSTOMER
- DETAILED BREAKDOWN TO FACILITATE COMPARISON AND ANALYSIS
- DOCUMENTED PRODUCTION PLAN AS BASIS FOR COST ESTIMATES
- CONSIDERATION OF ALTERNATIVE PRODUCTION METHODS
- ESTIMATES OF TIME TO REACH ANNUAL PRODUCTION LEVELS

SCOPE

- 4 POINT DESIGNS

  120 KW

  200 KW

  500 KW

  1600 KW

- 4 ANNUAL VOLUME LEVELS

  10 MW

  20 MW

  50 MW

  100 MW

- PROTOTYPE VOLUMES (1 UNIT AND 4 UNITS)

- CONCENTRATED USER APPLICATION (ANNUAL PRODUCTION INSTALLED AT ONE LOCATION)

- REASONABLE LEVEL OF DETAIL & ACCURACY

PRODUCTION PLAN OVERVIEW

ITEM/ACTIVITY	SOURCE
COMMERCIAL PARTS	COMMERCIAL VENDORS
MANUFACTURING	MANUFACTURING VENDORS
SITE PREP/ERECTION	CONSTRUCTION CONTRACTOR
ALL OTHER	VAWT, INC.

VAWT, INC. FUNCTIONS

- MARKETING/ENGINEERING

  MARKETING/SALES
  APPLICATIONS ENGINEERING
  SERVICE/TECHNICAL TRAINING
  FINAL ACCEPTANCE CHECK

- PURCHASING/SUBCONTRACTING

  COMMERCIAL PARTS
  MANUFACTURED PARTS
  SITE PREP/ERECTION

- WAREHOUSING/DISTRIBUTION

  RECEIVING
  INSPECTION
  STORAGE
  PACKAGING/SHIPPING
  INVENTORY PLANNING/CONTROL

- ADMINISTRATION

  GENERAL MGMT/PERSONNEL
  ACCOUNTING/PAYROLL

ASSUMPTIONS/GROUND RULES

- SINGLE VAWT DISTRIBUTION CENTER/WAREHOUSE

- ALL COMPONENTS RECEIVED, INSPECTED, STORED, PACKAGED & SHIPPED AT VAWT WAREHOUSE EXCEPT SITE PREP ITEMS

- VAWT LOCATED IN OKLAHOMA CITY, OKLAHOMA AREA

- 250 MILE AVERAGE TRANSPORTATION DISTANCE FOR COMPONENTS INBOUND TO VAWT WAREHOUSE AND OUTBOUND FROM VAWT TO INSTALLATION SITES

DETAIL PLAN DESCRIPTION

- PRODUCTION FLOW PLAN (PFP) SHOWS:
  - MAJOR SUBSYSTEMS/COMPONENTS ITEMS
  - PRODUCTION LOCATIONS
  - PRODUCTION FLOWS
  - BRIEF OPERATION DESCRIPTIONS
- DETAIL COST SHEETS PROVIDED UNDER SEPARATE COVER DEFINE:
  - DETAIL OPERATION STEPS
  - METHODS/TOOLS/EQUIPMENT UTILIZED

KEY FEATURES OF PRODUCTION PLAN

ROTOR BLADES

- ALUMINUM EXTRUDED SECTIONS
- MULTI-PIECE, KEYED & WELDED SECTIONS FOR LARGE BLADES
- ROLL FORMED SECTIONS

TOWER

- SPIRAL ROLLED & WELDED SECTIONS
- FLANGED FOR FIELD ASSEMBLY BOLTING

TIE DOWNS

- PURCHASED CABLES WITH TERMINATIONS
- FABRICATED TIE DOWN HARDWARE
- PURCHASED TENSIONING DEVICES

DRIVE TRAIN

- COMMERCIAL SPEED INCREASER
- COMMERCIAL DIFFERENTIAL (200 & 500 SYNCH)
- CLUTCH/BRAKE ASSEMBLED FROM COMPONENTS
- DRIVE TRAIN & GENERATOR PREASSEMBLED AT VAWT

ELECTRICAL

- COMMERCIAL GENERATOR, BREAKER/STARTER, XFMR
- CONTROL PANEL MANUFACTURED TO SPEC

SITE WORK

- GENERAL CONTRACTOR
- VAWT TECH ASSISTANCE
- ERECTION WITH CRANE

ALTERNATIVES

ALTERNATE BUSINESS ORGANIZATION

- COMPONENT MFGR TAKES ON VAWT FUNCTIONS
- POSSIBLE OVERHEAD & PROFIT REDUCTION
- IMPACT ON COST PROBABLY MINIMAL DUE TO NEED FOR SEPARATE ORG TO HANDLE VAWT FUNCTIONS
- VAWT APPROACH CONSERVATIVE

ALTERNATE TOWER ERECTION PROCEDURE

- PERMANENT ON SITE HYDRAULIC LIFTING DEVICE UTILIZED
- POSSIBLE LOWER COST IF SUFFICIENT UNITS AT ONE SITE
- WORKABILITY/COST BENEFIT SHOULD BE FURTHER EVALUATED

MONTHS TO REACH PRODUCTION LEVELS*

120 KW	9 MONTHS
200 KW	9 MONTHS
500 KW	12 MONTHS
1600 KW	14 MONTHS

*MANFACTURING LEAD TIME PLUS 3 MONTHS FOR PROCUREMENT CONTRACTS -- ASSUMES PRODUCTION CAPACITY AVAILABLE

LEAD TIMES AND MAXIMUM RATES

SPEED INCREASES	MONTHS FOR FIRST DELIVERY	MAXIMUM ANNUAL RATE
120 KW	5	180
200 KW	5	72
500 KW	9*	72
1600 KW	11*	48
BLADE SETS		
120 KW	6*	2400
200 KW	6*	960
500 KW	7	480
1600 KW	7	180
GENERATORS		
120 KW	5	240
200 KW	5	120
500 KW	5	96
1600 KW	8	48

*LIMITING ITEMS

ANNUAL PRODUCTION RATES

OUTPUT CAPACITY BUILT	- UNITS BUILT -			
	120 KW	200 KW	500 KW	1600 KW
10 MW	83	50	20	6
20 MW	170	100	40	12
50 MW	420	250	100	31
100 MW	830	500	200	62

COST ESTIMATING PROCEDURES

- COST ELEMENTS/SOURCES

- VENDORS CONTACTED

- COMMENTS ON METHODOLOGY

- FORMS/BACKUP STRUCTURE

COST ELEMENTS/SOURCES

PURCHASED ITEMS

- PURCHASE COST -- VENDOR QUOTES
- TRANSPORT COST -- VENDOR QUOTES
- VAWT G&A -- 10%[1]
- VAWT PROFIT -- 10%[1]

MANUFACTURING (VENDOR ESTIMATED)

- PURCHASE COST -- VENDOR QUOTES
- TRANSPORT COST -- VENDOR QUOTES
- VAWT G&A -- 10%[1]
- VAWT PROFIT -- 10%[1]

MANUFACTURING (KEARNEY ESTIMATED)

- DIRECT LABOR
- FACTORY OVERHEAD -- 110%
- DIRECT MATERIALS
- TOOLING (AMORTIZED OVER 1 YEAR)
- VENDOR G&A -- 34%[2]
- VENDOR PROFIT -- 7%[2]
- TRANSPORT COST
- VAWT G&A -- 10%[1]
- VAWT PROFIT -- 10%[1]

COST ELEMENTS/SOURCES (CON'T.)

SITE PREP/ERECTION (KEARNEY ESTIMATED)

- LABOR
- MATERIAL
- CONTRACTOR G&A -- 34%[3]
- CONTRACTOR PROFIT -- 7%[3]
- VAWT G&A -- 34%[1]
- VAWT PROFIT -- 7%[1]

VAWT INSPECTION/PACKAGING

- DIRECT LABOR
- FACTORY OVERHEAD -- 110%
- DIRECT MATERIALS
- TOOLING
- VAWT G&A -- 34%[2]
- VAWT PROFIT -- 7%[2]

1 BASED ON TROY'S "MANUAL OF PERFORMANCE RATIOS" FOR DISTRIBUTORS OF INDUSTRIAL MACHINERY

2 BASED ON TROY'S RATIOS FOR MANUFACTURERS OF HEAVY MACHINERY

3 FROM DISCUSSIONS WITH CONTRACTORS

VENDORS CONTACTED

Applied Power, Enerpac	Hydraulics
Bodine Electric	Motors
Kato Engineering	Motor/Generators
Hansen Transmission	Gear Box/Speed Increaser
Tube Forms, Inc.	Forming & Bending Blades
Lord Kinematics	Shock Absorbers
Lufkin Industries	Speed Increasers
Reynolds Aluminum	Extrusions (No Bid)
Kaiser Aluminum	Extrusions
Beall Pipe & Tank Co.	Tubular Mast
Rigging International	Erection & Site Prep.
Bigge Construction	Erection & Site Prep.
Granite Construction	Erection & Site Prep.
Baker, P. E.	General Contracting
FMC Corp.	Manufacturing
Lucker Mfg. Co.	Tensioning & Cables
Granger Industries	Motors
U. S. Steel Corp.	Tubes & Mast
Ryerson Steel	Materials
Ducommon	Materials
Flender Corp.	Speed Increasers
Aetna Machine Co.	Fabircation

VENDORS CONTACTED (CON'T.)

TUBE FORMS CO.	FABRICATION
ROTEK, INC.	BEARINGS
FAFNIR BEARING CO.	BEARINGS
BEARING ENGINEERING	BEARINGS
THE TOOL CRIB	HARDWARE (STANDARD)
VSL CORP.	HYDRAULIC JACKS
FALK GEAR CO.	GEAR BOXES/SPEED INCREASERS
COTTA GEAR WORKS	GEAR BOXES/SPEED INCREASERS
XTEK INC.	SPEED INCREASER
PHILADELPHIA GEAR WORKS	SPEED INCREASER/GEAR BOX
WATERMAN BRAKE CO.	BRAKE CALIPERS
LINCOLN ELECTRIC	MOTORS
ELECTRICAL CONTROLS CO., INC.	CONTROL BOX/PANEL

COMMENTS ON METHODOLOGY

- FOR TOWER SECTIONS, SITE WORK, AND MOST PURCHASED ITEMS

  - INDIVIDUAL ESTIMATES WERE DEVELOPED OR OBTAINED FOR EACH POINT DESIGN

- FOR MANUFACTURED ITEMS, WAREHOUSING OPERATIONS, EXTRUDED BLADES AND SOME PURCHASED ITEMS

  - ESTIMATES WERE DEVELOPED FOR 500 KW POINT DESIGN

  - ESTIMATES FOR OTHER POINT DESIGNS WERE CALCULATED ON THE BASIS OF WEIGHT RATIOS

    - OVERALL RATIOS FOR MINOR ITEMS*

120 KW	17,492#	.20
200 KW	41,312#	.44
500 KW	95,817#	1.00
1600 KW	283,910#	2.96

    - SPECIFIC RATIOS FOR MAJOR ITEMS

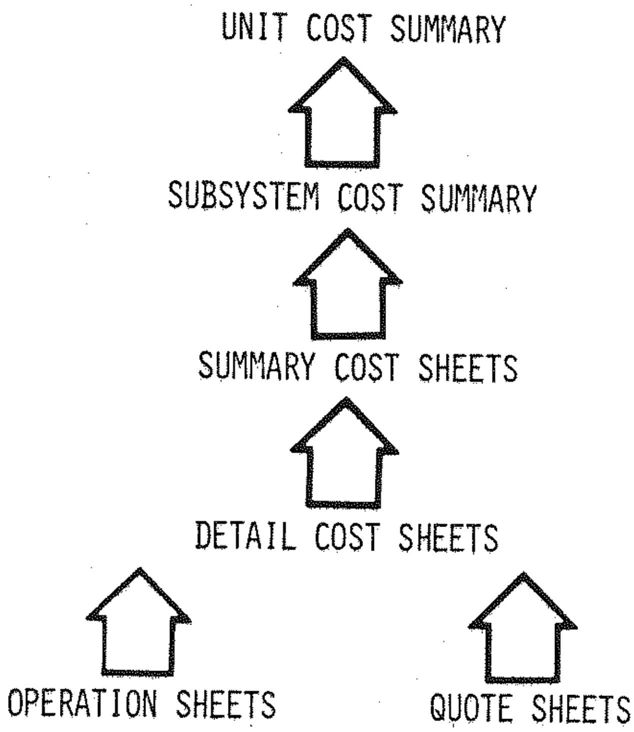
- WHERE MULTIPLE ESTIMATES WERE RECEIVED, A REASONABLE ESTIMATE WAS SELECTED

  - ESTIMATES WERE NOT AVERAGED

  - EXTREMELY HIGH OR LOW FIGURES WERE NOT USED

*BASED ON ORIGINAL DRAWINGS WHICH HAVE SINCE BEEN MODIFIED.

FORMS/BACKUP STRUCTURE



COST ESTIMATES

- UNIT COST SUMMARIES
- COST COMPARISONS
- SUBSYSTEM COSTS

SANDIA LABORATORIES

VAWT UNIT COST SUMMARY

Model: 120 KW

OPTION	COST/UNIT ANNUAL RATES					
	1	4	83	170	420	830
SYNCHRONOUS						
Fabrication	---NOT APPLICABLE---					
Site Prep/ Erection						
TOTAL COST						
INDUCTION						
Fabrication	154716	82455	55655	52617	50670	48950
Site Prep/ Erection	71520	69929	21486	20921	20374	19833
TOTAL COST	226236	152384	77141	73538	71044	68791

SANDIA LABORATORIES

VAWT UNIT COST SUMMARY

Model: 200 KW

OPTION	COST/UNIT ANNUAL RATES					
	1	4	50	100	250	500
SYNCHRONOUS						
Fabrication	280512	155303	112791	107659	102263	99511
Site Prep/ Erection	81588	79609	24401	23773	23148	22522
TOTAL COST	362100	243912	137192	131432	125411	122033
INDUCTION						
Fabrication	293691	169205	126292	120393	114324	111086
Site Prep/ Erection	81588	79609	24401	23773	23148	22522
TOTAL COST	375279	248814	150693	144166	137472	133608

SANDIA LABORATORIES

VAWT UNIT COST SUMMARY

Model: 500 KW

OPTION	COST/UNIT ANNUAL RATES					
	1	4	20	40	100	200
SYNCHRONOUS						
Fabrication	497065	302910	240405	226509	212599	202189
Site Prep/ Erection	95326	92033	43446	41453	40643	39828
TOTAL COST	592391	394943	283851	267962	253242	249017
INDUCTION						
Fabrication	505335	311203	248281	233868	219372	215311
Site Prep/ Erection	95326	92033	43446	41453	40643	39828
TOTAL COST	600661	403236	291727	275321	260015	255139

SANDIA LABORATORIES

VAWT UNIT COST SUMMARY

Model: 1600 KW

OPTION	COST/UNIT ANNUAL RATES					
	1	4	6	12	31	62
SYNCHRONOUS						
Fabrication	1187956	754209	683844	632112	593102	543512
Site Prep/ Erection	237860	235134	82426	80177	77973	75570
TOTAL COST	1425818	989343	766270	712289	671075	619082
INDUCTION						
Fabrication	1187956	754209	683844	632112	593102	543512
Site Prep/ Erection	237860	235134	82426	80177	77973	75570
TOTAL COST	1425818	989343	766270	712289	671075	619082

VAWT

$/KW-HR/YR

POINT DESIGN	ANNUAL PRODUCTION RATE (MW) 10	20	50	100
120 KW	.309	.294	.284	.275
200 KW	.311	.298	.284	.276
500 KW	.278	.263	.248	.243
1600 KW	.263	.244	.230	.212

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 120 KW

SUBSYSTEM	Cost/Unit At Annual Rates: 1	4	83	170	420	830	Dollars/Pound[1]	Estimate Source[2]
A. ROTOR BLADES								
1. Blade Sections	78124	24711	7407	6898	6582	6436	1.86	V
2. VAWT Packaging	88	88	88	88	88	88		KF
B. TOWER								
1. Flanged Tower Sections	21412	8399	4591	4493	4436	4418	.75	V
2. Upper Tie Down Attachments	614	421	303	278	253	234		KF
3. Upper Bearing and Housing	824	822	821	818	728	726		VF
4. Lightning Arrestor	2500	2424	900	877	861	844		KVF
5. VAWT Packaging (Items 1-4)	1329	893	893	893	893	893		K
6. Upper Cone Assembly	4033	1857	1175	1273	1246	1240		VF
7. Universal Joint	4433	4018	3005	2743	2256	2126		KF
8. Lower Cone Assembly	3661	1608	1564	989	973	967		VF
9. VAWT Packaging (Items 6-8)	96	96	96	96	96	96		KF
10. Hardware	81	80	80	80	80	80		KF

Note: (1) Dollars/pound on first non-prototype rate (10 MW/yr).
(2) Estimate Codes: K=Kearney, V=Vendor and F=Factored based on another model.

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 120 KW

SUBSYSTEM	Cost/Unit At Annual Rates: 1	4	83	170	420	830	Dollars/ Pound	Estimate Source
C. TIE DOWNS								
1. Cable with terminations	8194	8194	8194	8194	8194	7392	4.11	VF
2. Cable attachment hardware	361	325	289	232	196	160	--	KF
3. Tension Devices	1068	1068	798	789	714	702		V
4. VAWT packaging (Items 1-3)	85	78	71	61	55	48		KF
5. Tiedown plate	816	795	709	688	663	645		KF
D. DRIVE TRAIN								
1. Speed Increaser	9419	9419	9419	8666	8666	8666	4.71	V
2. Differential gearbox (200 & 500 sync only)	--	--	--	--	--	--		V
3. Clutch and/or brake assembly	4258	4233	3815	3463	3023	2925	7.80	KF
4. Preassembly	409	393	377	360	344	328		KF
E. ELECTRICAL								
1. Generator (Sync)	--	--	--	--	--	--	4.55	V
Generator (Ind)	2676	2659	1821	1735	1718	1706		V
2. Breaker/ Starter (Sync)	--	--	--	--	--	--		V
Breaker/ Starter (Ind)	6626	6499	6318	6004	5767	5595		V

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 120 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	83	170	420	830	Dollars/ Pound	Estimate Source
E. ELECTRICAL (Cont.)								
3. Transformer (Sync)	--	--	--	--	--	--		V
Transformer (Ind)	--	--	--	--	--	--		V
4. Control Panel	3609	3375	2921	2899	2838	2643		K
TOTAL FAB. (Sync)	--	--	--	--	--	--		
TOTAL FAB. (Ind)	154716	82455	55655	52617	50670	48950		
F. SITE WORK								
1. Grading/ Foundations) 2. Assembly/ Erection) --	64521	64521						
1. Grading/ Foundations			10843	10651	10372	10101		K
2. Assembly/ Erection			5084	4951	4823	4693		K
3. Fencing/Painting	6999	5408	5459	5319	5179	5039		K
TOTAL SITE WORK	71520	69929	21486	20921	20374	19833		
TOTAL COST SYNCHRONOUS	--	--	--	--	--	--		
TOTAL COST INDUCTION	226236	152384	77141	73538	71044	68791		

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 200 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	50	100	250	500	Dollars/Pound[1]	Estimate Source[2]
A. ROTOR BLADES								
1. Blade Sections	136789	44316	15905	14545	13674	13302	2.19	V
2. VAWT Packaging	194	194	194	194	194	194		KF
B. TOWER								
1. Flanged Tower Sections	35248	14980	9032	8774	8622	8570	.61	V
2. Upper Tie Down Attachments	978	697	490	453	414	384		KF
3. Upper Bearing and Housing	1404	1402	1401	1217	1207	1205		VF
4. Lightning Arrestor	2828	2673	1102	1063	1011	991		KVF
5. VAWT Packaging (Items 1-4)	1329	893	893	893	893	893		K
6. Upper Cone Assembly	7989	3607	2396	2342	2298	2287		VF
7. Universal Joint	6323	5698	4634	4343	3457	3272		KF
8. Lower Cone Assembly	8052	3549	2232	2176	2131	2119		VF
9. VAWT Packaging (Items 6-8)	211	211	211	211	211	211		KF
10. Hardware	126	116	116	114	114	114		KF

Note: (1) Dollars/pound on first non-prototype rate (10 MW /yr).
(2) Estimate Codes: K=Kearney, V=Vendor and F=Factored based on another model.

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 200 KW

SUBSYSTEM	Cost/Unit At Annual Rates: 1	4	50	100	250	500	Dollars/ Pound	Estimate Source
C. TIE DOWNS								
1. Cable with terminations	20920	20920	20920	20920	18871	18871	4.11	V
2. Cable attachment hardware	454	454	413	350	350	310		KF
3. Tension Devices	2316	2316	1632	1614	1605	1443		V
4. VAWT packaging (Items 1-3)	100	97	88	79	75	66		KF
5. Tiedown plate	1795	1749	1559	1514	1459	1419		KF
D. DRIVE TRAIN								
1. Speed Increaser	23354	23354	23354	21486	21486	21486	4.44	V
2. Differential gearbox (200 & 500 sync only)	1644	1644	1644	1644	1644	1644	1.91	V
3. Clutch and/or brake assembly	6300	6271	5465	5152	4403	4302	9.04	KF
4. Preassembly	542	520	499	477	456	434		KF
E. ELECTRICAL								
1. Generator (Sync)	6789	6458	6042	6012	5995	5983		V
Generator (Ind)	6789	6458	6042	6012	5995	5983		V
2. Breaker/ Starter (Sync)	6622	6495	6314	5940	5645	5424		V
Breaker/ Starter (Ind)	6622	6495	6314	5940	5645	5424		V

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 200 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	50	100	250	500	Dollars/ Pound	Estimate Source
E. ELECTRICAL (Cont.)								
3. Transformer (Sync)	4581	3487	3334	3244	3243	3243		V
Transformer (Ind)	19404	19033	18479	17622	16948	16462		V
4. Control Panel	3614	3333	2921	2902	2805	2643		K
TOTAL FAB. (Sync)	280512	155303	112791	107659	102263	99511		
TOTAL FAB. (Ind)	293691	169205	126292	120393	114324	111086		
F. SITE WORK								
1. Grading/ Foundations) 2. Assembly/ Erection) --	71690	71690	10996	10713	10432	10149		K
2. Assembly/ Erection			5684	5538	5392	5246		K
3. Fencing/Painting	9898	7919	7721	7522	7324	7127		K
TOTAL SITE WORK	81588	79609	24401	23773	23148	22522		
TOTAL COST SYNCHRONOUS	362100	234912	137192	131432	125411	122033		
TOTAL COST INDUCTION	375279	248814	150693	144166	137472	133608		

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 500 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	20	40	100	200	Dollars/ Pound [1]	Estimate Source [2]
A. ROTOR BLADES								
1. Blade Sections	226696	77525	35750	30500	27237	25997	2.81	V
2. VAWT Packaging	440	440	440	440	440	440		K
B. TOWER								
1. Flanged Tower Sections	48771	26112	20067	19212	18648	18384	.70	V
2. Upper Tie Down Attachments	2816	2115	1518	1384	1265	1176		K
3. Upper Bearing and Housing	2182	2180	1916	1913	1445	1381		V
4. Lightning Arrestor	3607	3254	1620	1511	1423	1334		KV
5. VAWT Packaging (Items 1-4)	1329	893	893	893	893	893		K
6. Upper Cone Assembly	17222	7657	4956	4835	4753	4729		V
7. Universal Joint	10735	10549	8370	8124	6682	6231		K
8. Lower Cone Assembly	18300	8068	5074	4943	4967	4840		V
9. VAWT Packaging (Items 6-8)	479	479	479	479	479	479		K
10. Hardware	121	121	121	119	119	119		K

Note: (1) Dollars/pound on first non-prototype rate (10 MW/yr).
(2) Estimate Codes: K=Kearney, V=Vendor and F=Factored based on another model.

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 500 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	20	40	100	200	Dollars/ Pound	Estimate Source
C. TIE DOWNS								
1. Cable with terminations	42732	42732	42732	42732	38547	38547	4.11	VF
2. Cable attachment hardware	986	916	845	775	704	634		K
3. Tension Devices	3453	3453	2622	2367	2352	2334		V
4. VAWT packaging (Items 1-3)	167	155	143	130	120	108		K
5. Tiedown plate	4080	3974	3543	3441	3316	3226		K
D. DRIVE TRAIN								
1. Speed Increaser	63696	63696	63969	58560	57389	57389	2.93	V
2. Differential gearbox (200 & 500 sync only)	6685	6685	6685	6685	6685	6685	1.91	V
3. Clutch and/or brake assembly	10553	10502	9464	8771	7528	7356	9.16	K
4. Preassembly	602	578	554	530	506	482		K
E. ELECTRICAL								
1. Generator (Sync)	11636	11038	10649	10619	10271	10359	2.78	V
Generator (Ind)	11636	11038	10649	10619	10271	10259		V
2. Breaker/ Starter (Sync)	9185	9009	8760	8330	7996	7769		V
Breaker/ Starter (Ind)	9185	9009	8760	8330	7996	7769		V

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 500 KW

SUBSYSTEM	Cost/Unit At Annual Rates: 1	4	20	40	100	200	Dollars/ Pound	Estimate Source
E. ELECTRICAL (Cont.)								
3. Transformer (Sync)	6436	6316	6149	5878	5608	5358		V
Transformer (Ind)	21391	21294	20710	19922	19066	18165		V
4. Control Panel	4156	3833	3359	3338	3226	3039		K
TOTAL FAB. (Sync)	497065	302910	240405	226509	212599	209189		
TOTAL FAB. (Ind)	505335	311203	248281	233868	219372	215311		
F. SITE WORK								
1. Grading/ Foundations) 2. Assembly/ Erection) --	78859	78859						
1. Grading/ Foundations			14197	12955	12894	12831		K
2. Assembly/ Erection			16404	15983	15563	15141		K
3. Fencing/Painting	16467	13174	12845	12515	12186	11856		K
TOTAL SITE WORK	95326	92033	43446	41453	40643	39828		
TOTAL COST SYNCHRONOUS	592391	394943	283851	267962	253242	249017		
TOTAL COST INDUCTION	600661	403236	291727	275321	260015	255139		

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 1600KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	6	12	31	62	Dollars/Pound[1]	Estimate Source[2]
A. ROTOR BLADES								
1. Blade Sections	554391	223443	184307	147376	124282	91365	2.99	V
2. VAWT Packaging	1302	1302	1302	1302	1302	1302		KF
B. TOWER								
1. Flanged Tower Sections	92440	57832	53980	50136	47772	47028	.60	V
2. Upper Tie Down Attachments	7953	5551	3948	3383	3118	2755		KF
3. Upper Bearing and Housing	2700	2698	2697	2694	2684	2682		VF
4. Lightning Arrestor	6336	5290	4776	4506	2804	2542		KVF
5. VAWT Packaging (Items 1-4)	3934	2643	2643	2643	2643	2643		K
6. Upper Cone Assembly	45618	18984	10975	10623	10406	10335		VF
7. Universal Joint	26171	23341	21743	20895	16062	15308		KF
8. Lower Cone Assembly	49820	20620	11755	11376	11141	11063		VF
9. VAWT Packaging (Items 6-8)	1418	1418	1418	1418	1418	1418		KF
10. Hardware	204	204	204	204	204	204		KF

Note: (1) Dollars/pound on first non-prototype rate (10 MW/yr).
(2) Estimate Codes: K=Kearney, V=Vendor and F=Factored based on another model.

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 1600 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	6	12	31	62	Dollars/ Pound	Estimate Source
C. TIE DOWNS								
1. Cable with terminations	129665	129665	129665	129665	129665	116965	4.11	V
2. Cable attachment hardware	2808	2563	2523	2523	2523	2523		KF
3. Tension Devices	15327	12753	12732	12087	12084	11439		V
4. VAWT packaging (Items 1-3)	468	453	435	422	409	396		KF
5. Tiedown plate	12077	11763	10487	10185	9815	9549		KF
D. DRIVE TRAIN								
1. Speed Increaser	157071	157071	157071	151166	151166	151166	3.41	V
2. Differential gearbox (200 & 500 sync only)	--	--	--	--	--	--		V
3. Clutch and/or brake assembly	36981	36700	32982	31018	26408	26249	5.74	KF
4. Preassembly	903	867	831	795	759	723		KF
E. ELECTRICAL								
1. Generator (Sync)	22027	21574	21301	21271	20816	20804	2.01	V
Generator (Ind)	22027	21574	21301	21271	20816	20804		V
2. Breaker/ Starter (Sync)	13242	12874	12038	12339	11750	11411		V
Breaker/ Starter (Ind)	13242	12874	12038	12339	11750	11411		V

SANDIA LABORATORIES

VAWT SUBSYSTEM COST SUMMARY

Model: 1600 KW

SUBSYSTEM	Cost/Unit At Annual Rates 1	4	6	12	31	62	Dollars/ Pound	Estimate Source
E. ELECTRICAL (Cont.)								
3. Transformer (Sync)	--	--	--	--	--	--		V
Transformer (Ind)	--	--	--	--	--	--		V
4. Control Panel	5102	4600	4031	4094	3871	3647		K
TOTAL FAB. (Sync)	1187956	754209	683844	632112	593102	543512		
TOTAL FAB. (Ind)	1187956	754209	683844	632112	593102	543512		
F. SITE WORK								
1. Grading/ Foundations) 2. Assembly/ Erection)	215070	215070						
1. Grading/ Foundations			33156	32306	31456	30606		K
2. Assembly/ Erection			29942	29175	28407	27639		K
3. Fencing/Painting	22790	20064	19328	18696	18110	17325		K
TOTAL SITE WORK	237860	235134	82426	80177	77973	75570		
TOTAL COST SYNCHRONOUS	1425818	989343	766270	712289	671075	619082		
TOTAL COST INDUCTION	1425818	989343	766270	712289	671075	619082		

DOLLAR COST PER POUND COMPARISON*

(AT 10 MW PER YEAR)

PERCENT FAB. COST IN 1600 KW	ITEM	120 KW	200 KW	500 KW	1600 KW
27%	BLADES WITH CLAMPS/JOINTS	1.86	2.19	2.81	2.98
8	TOWER SECTIONS WITH FLANGES	.75	.61	.70	.60
3	UPPER & LOWER CONES	2.30	1.83	1.46	1.51
-	UPPER BEARING/ HOUSING	8.55	14.59	6.14	5.57
1	UPPER TIEDOWN ATTACH	NO WEIGHT	.64	1.00	.62
3	UNIVERISAL JOINT	6.43	5.18	2.34	2.03
1	ARRESTOR/HDWE	6.00	4.21	4.50	4.14
19	CABLES & SOCKETS	4.11	4.11	4.11	4.11
4	CABLE TIEDOWNS	1.32	1.45	1.72	2.79
23	GEARBOX	4.71	4.45	2.93	3.41
-	DIFFERENTIAL	-	1.91	1.91	-
5	CLUTCH/BRAKE	7.80	9.05	6.47	5.75
3	GENERATOR	1.44	2.55	1.74	2.01
OVERALL (INDUCTION)		4.04	3.47	2.96	2.65
EXCLUDING INSTALLATION		2.91	2.91	2.52	2.37

*BASED ON WEIGHTS SHOWN ON FOLLOWING PAGE.

WEIGHT TABLE*

	120 KW	200 KW	500 KW	1600 KW
BLADES, CLAMPS & JOINTS	3982	7270	12702	61772
TOWER SECTIONS WITH FLANGES	4504 (6112)	13095 (14397)	18340 (28724)	59236 (90064)
UPPER & LOWER CONES	1190	2535	6887	15085
UPPER BEARING & HOUSING	96	96	312	484
UPPER TIEDOWN ATTACHMENT	NOT SHOWN	760	1518	6334
U JOINT	467	895	3569	10707
ARRESTOR & HDWE	150	262	360	1154
CABLES & SOCKETS	1992	5085	10387	31518
CABLE TIEDOWNS	1362	2490	4071	9234
GEARBOX	2000	5250	21800	46000
DIFFERENTIAL	--	860	3494	
CLUTCH/BRAKE	489	604	1033	5740
GENERATOR	1260	2370	3830	10600
BREAKER/STARTER				
TRANSFORMER				
TOTAL DRAWING	17492	41572	88303	257864
TOTAL WITH REVISED TOWER	(19100)	(43374)	(98687)	(288692)

*ALL WEIGHTS FROM DRAWINGS EXCEPT TOWER WEIGHTS IN ( ) FOR REVISED TOWER DESIGN FOR ROLL FORMING.

COST/POUND COMPARISON

(AT 10 MW/YEAR)

	120 KW	200 KW	500 KW	1600 KW
ROTOR BLADES	1.24	2.14	2.39	2.94
TOWER	.59	.62	.70	1.11
CABLES	4.11	4.12	4.00	4.12
SPEED INCREASE	3.04	3.54	3.40	5.82
DIFFERENTIAL	----	1.16	2.07	----
CLUTCH/BRAKE	1.07	1.02	.89	1.00
GENERATOR	4.55	2.55	2.78	2.01

APPENDIX C - The Alcoa Study

Table of Contents

C1 - Alcoa Executive Summary

PARAMETRIC OPTIMIZATION STUDY

DARRIEUS TYPE

VERTICAL AXIS WIND TURBINES

PHASE II

Point Designs
Business Scenarios
Cost Estimates
Conclusions

Final Report - Executive Summary

By

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TABLE OF CONTENTS

ABSTRACT

Sandia Laboratories has developed advanced technology for Wind Energy Conversion Systems utilizing Darrieus-type Vertical Axis Wind Turbines, and has constructed two prototypes in Albuquerque, New Mexico, to demonstrate the adequacy of that technology.

In an effort to optimize design and cost effectiveness of future Vertical Axis Wind Turbines, Sandia initiated a Parametric Optimization Study and contracted with Aluminum Company of America to bring practical business considerations of purchasing, fabrication, marketing, administration, delivery and site construction to bear on the designs and to establish Business Scenarios and estimating formats as a base for cost estimating and analysis. That work was performed by Alcoa as Phase I of a two part contract and was reported on 1978 January 25.

Phase II of the two-part contract involved the actual cost estimating and business analyses. The results of that work are reported in this Executive Summary with appendices presenting drawings, specifications and raw cost data which were the basis for the Summary data and Conclusions.

SECTION 1

INTRODUCTION

Aluminum Company of America (Alcoa) and Sandia Laboratories personnel started work on 1977 September 01 to evolve and refine a study that would establish realistic installed costs of Darrieus-type Vertical Axis Wind Turbines (VAWTs), such as the five-meter and 17-meter diameter prototypes that had been designed and constructed by Sandia in Albuquerque, New Mexico.

That study became known as a "Parametric Optimization Study" as the many design, specification, fabrication, distribution, delivery, construction and wind condition variables became better understood.

The objectives of the study were established as:

- Providing economically optimum and structurally adequate system configurations for Vertical Axis Wind Turbines.

- Identifying cost trends and serving as a design tool for making technical decisions on an economic basis.

- Providing a capability to rapidly estimate the absolute cost of VAWT electrical energy for a wide variety of operating and configurational conditions.

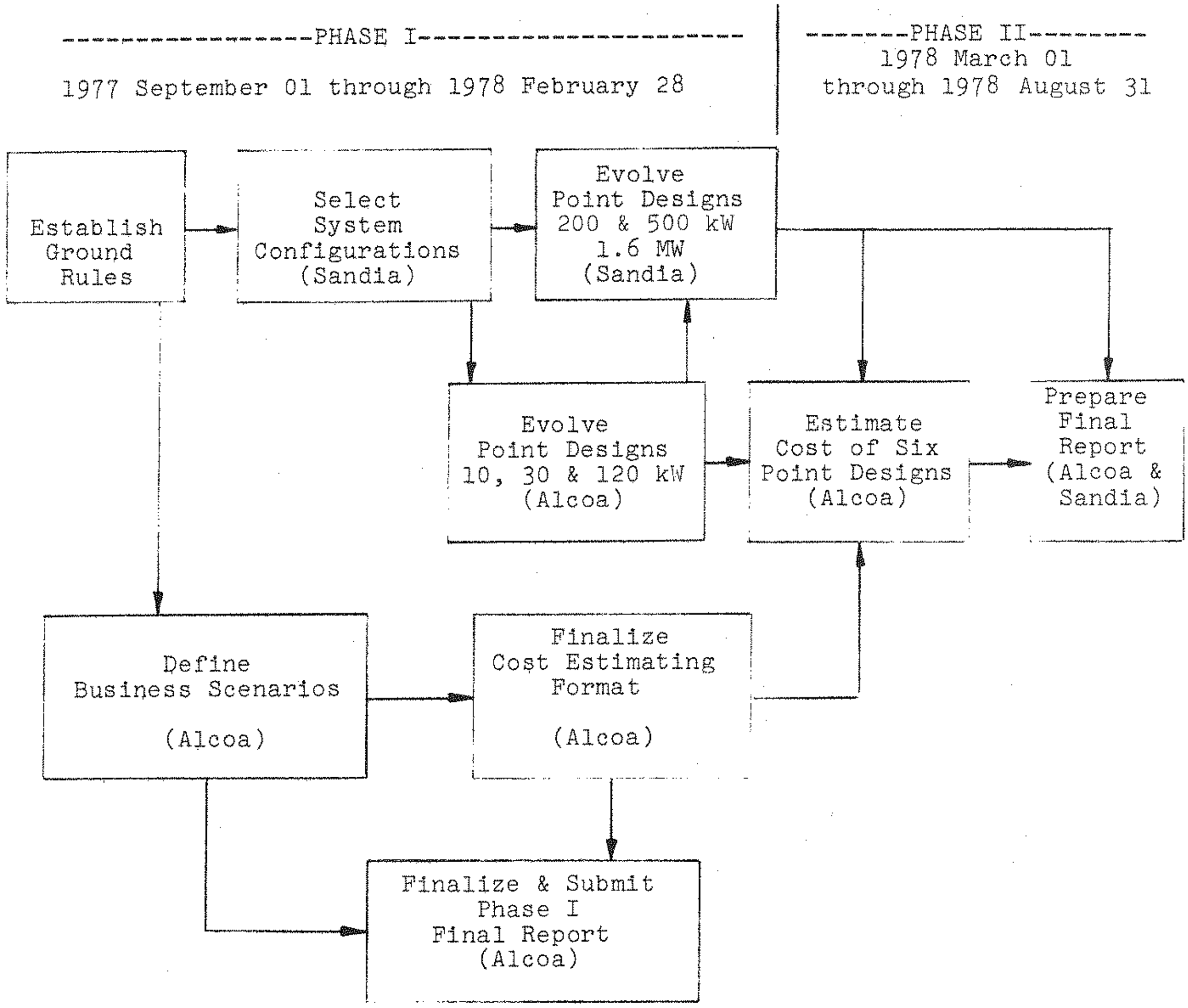
There was general acceptance that a range of electricity-generating capacity sizes would be necessary to accommodate the many different applications and users that are perceived for cost-effective Wind Energy Conversion Systems. There was also agreement that costs of VAWTs are sensitive to volume of production and to the type of business venture that would fabricate and market the VAWT systems and their key subsystems and components.

Phase I of this study established "Business Scenarios" that relate to four different annual production volumes and two basic business ventures intended to serve electricity-generating utilities (Scenario #1) and non-utility electricity users (Scenario #2). Six "Point Designs" were selected to illustrate specific VAWTs that would be typical of those business ventures and target markets.

This report summarizes work performed in Phase II of the study which evolved the cost estimates relative to each "Business Scenario".

Page 2 of this Section illustrates the scope of the Parametric Optimization Study that evolved and the breakdown of tasks and flow of data that has led to this report.

ALCOA/SANDIA LABORATORIES
DARRIEUS TYPE
VERTICAL AXIS WIND TURBINES
PARAMETRIC OPTIMIZATION STUDY



TOTAL PROJECT FLOW
1977 September 01 through 1978 August 31

1.1 Ground Rules

In addition to system design ground rules established by Sandia (not covered in this report) to "freeze" the state-of-the-art technology and allow point designs of reliable electricity-generating hardware to be prepared, additional ground rules were accepted for the total study so that many potential variables could be removed and specific meaningful costs could be established under defined conditions.

Some of the principal ground rules were:

- Optimization based on minimizing annual operating cost per unit of energy supplied.
- 15 mph average wind speed distribution for design and optimization purposes. The impact on design and performance of 12 and 18 mph wind regimes will also be considered.
- Wind shear exponent of .17 from a reference height of 30 feet.
- Rotor blades constructed from hollow, thin-walled aluminum extrusions, using existing manufacturing capabilities.
- Annual cost to the owner of owning and operating the turbine is taken as 12, 15 and 18% of the installed cost.
- Electrical -- to be constant rpm, grid controlled; control system to permit unmanned operation.
- Structural -- all components designed for infinite fatigue life under normal operating conditions.
- One target market is electricity-generating utilities.
- A second target market is non-utility electricity users.
- Business ventures utilized in cost estimates will be privately owned "Greenfield" companies -- as opposed to subsidiaries or modifications of existing businesses -- identified as SANVAWT (acronym for Sandia Vertical Axis Wind Turbines).
- Annual quantities of VAWTs for production cost estimates will be based on peak electricity-generating capacities of approximately 10, 20, 50 and 100 megawatts.
- No market analysis or value justifications were attempted in the scope of the study.

Other ground rules, or clarifying assumptions, are included in each Business Scenario.

1.2 System Configurations and Point Designs

System configurations were selected by Sandia based on computer programs and background data not covered in this report. The product line summarized on the next page evolved from Sandia's efforts to produce the optimum size and design of VAWTs with nominal capacities of 200, 500 and 1600 kW and adding smaller sizes (30 and 120 kW) based on Alcoa work under DOE contracts for low cost VAWTs to be prototyped at the Rocky Flats test site near Denver, Colorado. The sixth design (10 kW) is an extension of Alcoa work on a demonstration VAWT in Potsdam, New York, which was designed by Clarkson College mechanical engineering personnel based on Sandia technology and the five-meter Sandia prototype. Each of the system configurations is representative of nominal capacities for specific applications.

Sandia has also initiated system design for a nominal 3500 kW VAWT, but it is believed to be too complex and preliminary to be within the scope or time limits of this contract.

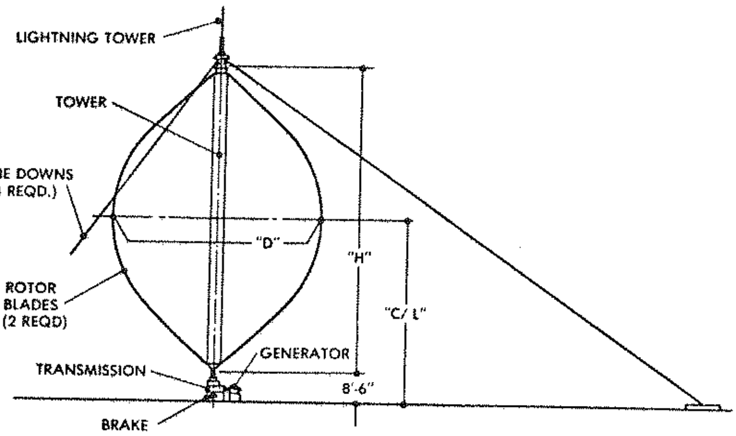
For purposes of this study the four larger machines are assumed to be utilized by electricity-generating utilities or other large, concentrated users. Those four machines comprise the product line for one Business Scenario, #1, which is described in detail on Pages 1-1 through 1-50 of this report.

The two smallest machines, as well as the smaller two (120 and 200 kW) utilized in Scenario #1, comprise the product line for Scenario #2, covered on pages 2-1 through 2-50 of this report. That Scenario assumes that the user is not a utility.

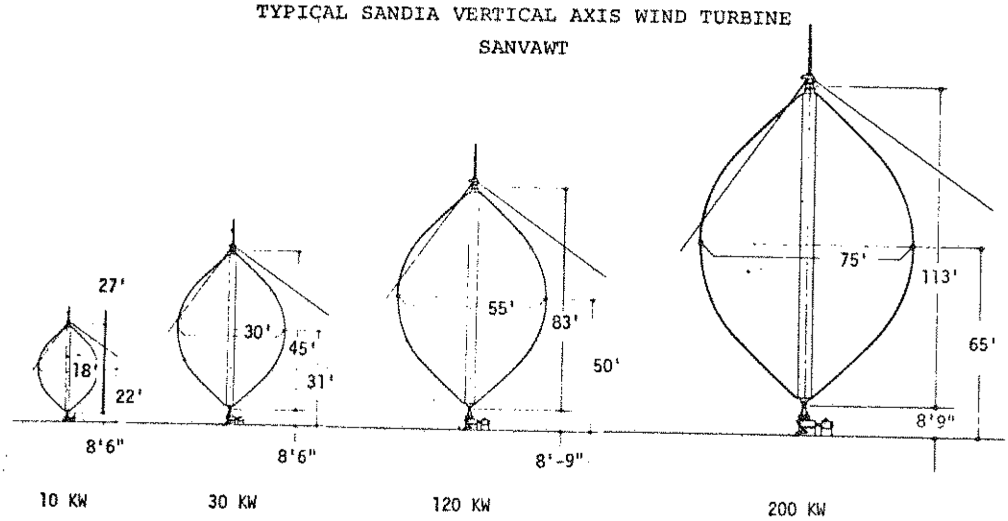
All of the VAWT system configurations are based on two-blade rotors with a height-to-diameter ratio of 1.5.

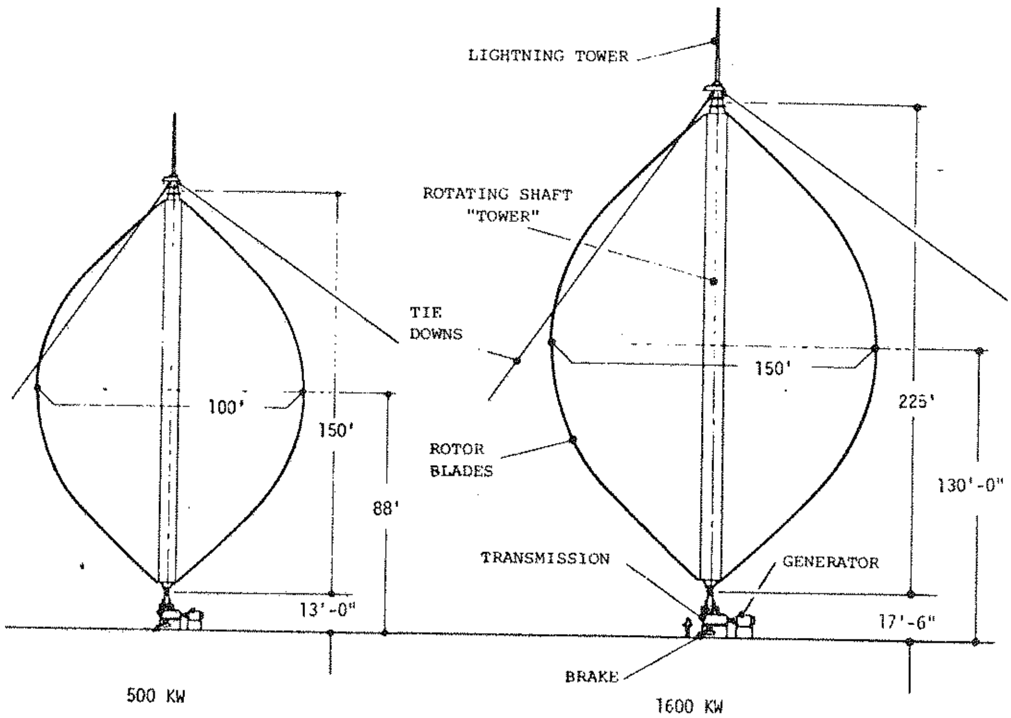
Sandia Laboratories produced the point designs for the 200, 500 and 1600 kW capacity VAWTs with critiques and practical fabrication consultation by Alcoa. Alcoa Laboratories produced the point designs for the 10, 30 and 120 kW capacity machines with basic technological input from Sandia to keep the design assumptions and performance data consistent for all of the SANVAWT product line.

A typical SANVAWT VAWT, with its major subsystems and components identified, is shown along with illustrations of the six point designs on Page 5. Additional general product data is shown on Page 6. Detailed drawings and specifications are included in the appendices.



TYPICAL SANDIA VERTICAL AXIS WIND TURBINE
SANVAWT





SANVAWT, INC. POINT DESIGNS

SANVAWT, INC.

Point Designs -- Product Line

Designation Nominal Size - Rating	Rotor Height/ Diameter (Feet)	Wind Regime (mph)	Rated* Power (kW)	Annual* Output (kWh)	Rotor Speed (rpm)
2718 - 10 kW	27 x 18	12	5	8,480	147
		15	9	16,400	174
		18	16	30,100	204
4530 - 30 kW	45 x 30	12	18	30,200	86
		15	30	60,000	100
		18	50	104,800	119
8355 - 120 kW	83 x 55	12	80	135,600	47
		15	120	250,000	54
		18	210	481,300	63
11375 - 200 kW	113 x 75	12	135	265,000	34
		15	220	493,000	41
		18	390	890,000	48
150100 - 500 kW	150 x 100	12	285	574,000	26
		15	480	1,070,000	31
		18	935	1,980,000	37
225150 - 1.6 MW	225 x 150	12	935	1,670,000	19
		15	1600	3,000,000	23
		18	2700	5,640,000	26

* Rated power and annual output are determined for a typical 12, 15 and 18 mph median wind speed distribution at sea level. Rotor rpm selected on the basis of minimizing cost per unit of annual energy delivered.

1.3 Business Scenarios

To develop realistic costs of installed Vertical Axis Wind Turbines, Business Scenarios were defined for two basic business ventures and target users -- electricity-generating utilities and non-utility electricity users -- with four different annual production requirements -- approximately 10, 20, 50 and 100 MW of installed electricity capacity -- for each.

Therefore, a total of eight different business scenarios were developed and cost estimates relative to each were prepared to illustrate the effect on costs relative to different production quantities, purchased materials quantities, marketing approaches, capital requirements and means of implementing site work. The specific variables are described in the Business Scenario Summaries -- 1a, 1b, 1c, and 1d and 2a, 2b, 2c, and 2d which follow the conclusions at the end of this section.

The methodology utilized to develop the cost data presented was a combination of securing actual quotations from existing suppliers of relative hardware, reducing those quotations to their basic labor and material contents and building those costs back up to selling prices by adding the production overhead, corporate overhead and profit defined in each scenario. In some cases, actual man-hours and purchased material costs utilized in the vendor quotations were known, while in others the direct cost data had to be interpolated. In converting direct man-hours into direct labor costs a labor rate of $5.00 per hour and a 30% benefits adder were utilized. Those figures are approximately the mean of 18 Alcoa domestic subsidiaries. In some parts of the country the cost would be lower, while in others it would be higher.

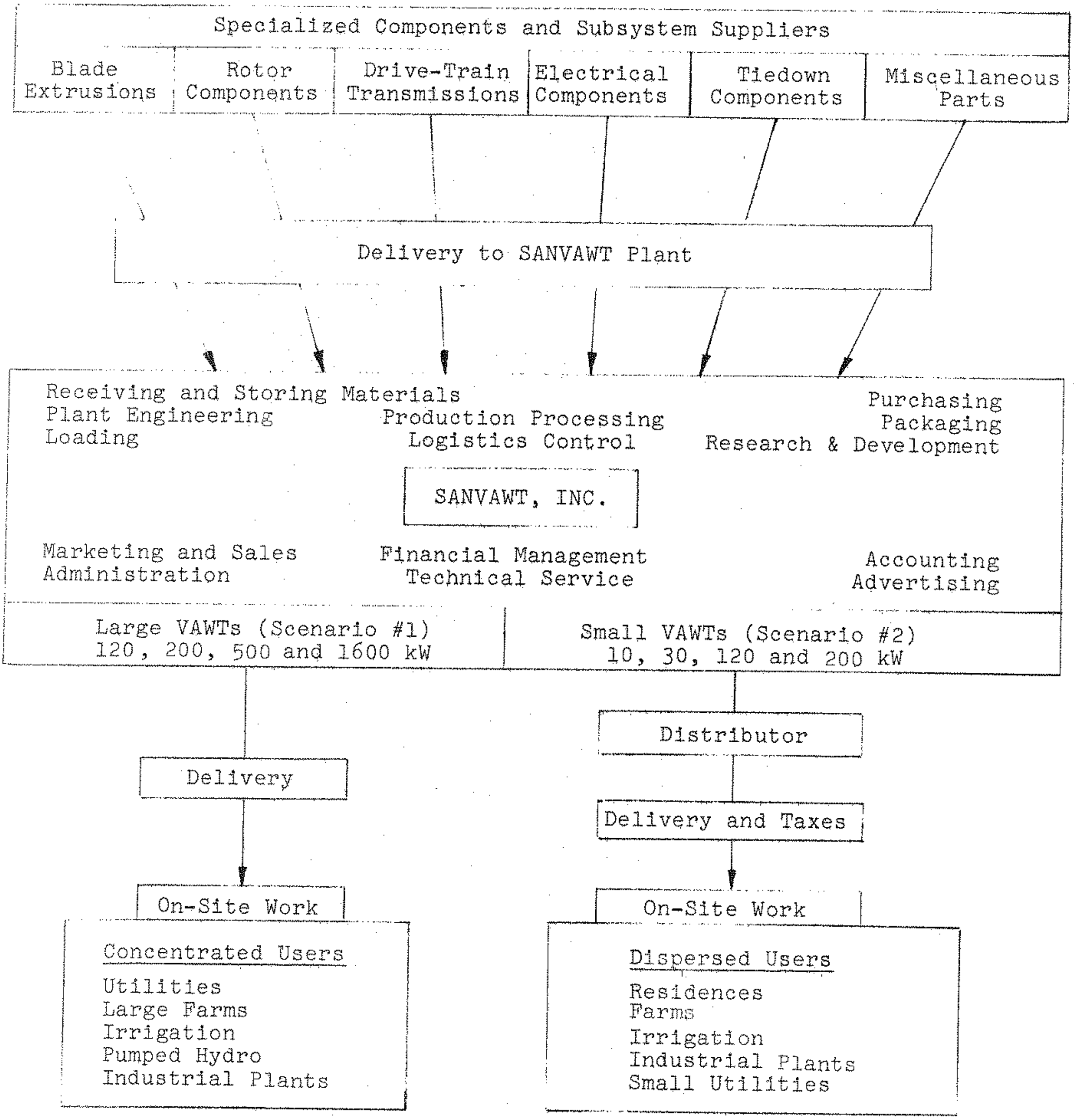
The common goal of all eight scenarios is a return on capital in use of 40% before federal taxes. That target was established based on published recommendations of the American Management Associations.

Line item costs are realistically comparable within the major scenarios -- #1 and #2 -- but not between those scenarios because of the different basic assumptions and the fact that Scenario #2 represents a much more "active" or "busy" operation with many more units produced and sold to account for the same volume of kW or dollars as in Scenario #1.

An illustration of the general business scenarios and flow of products and activities is shown on Page 8.

SANVAWT, INC.

ILLUSTRATION OF BUSINESS SCENARIOS AND FLOW OF PRODUCTS



- SCENARIO #1 -

- SCENARIO #2 -

1.4 Conclusions

The summaries on Pages 10 through 14 show the costs of the VAWT point designs. The chart on Page 10 presents the costs summarized by the illustrative VAWT size while the final four pages show the costs by Business Scenario. Following Page 14, each Business Scenario is presented in greater detail.

Appendix B -- Raw Cost Data -- includes an Alcoa Laboratories estimate of the cost to fabricate and install the first unit of each size. As a check against that estimate, as well as costs projected in the various Business Scenarios, an Alcoa subsidiary -- L. W. Nash Company -- quoted on the fabrication and erection of the first unit. Those two "first unit" costs are:

Item	Designation	Alcoa Laboratories Estimate	L. W. Nash Quote
1	2718 - 10 kW	$ 77,150	$ 83,750
2	4530 - 30 kW	$ 97,930	$ 96,500
3	8355 - 120 kW	$ 193,490	$ 192,050
4	11375 - 200 kW	$ 289,540	$ 264,415
5	150100 - 500 kW	$ 517,250	$ 494,300
6	225150 - 1.6 MW	$1,263,230	$1,309,310

From this in-depth analysis of all elements of cost that build up to the cost of the electricity produced by the installed VAWTs, it can be concluded that the mid-sized VAWTs -- 30, 120 and 200 kW -- appear ready for serious commercialization-oriented product development and demonstration efforts. The smallest unit -- 10 kW -- appears to be too costly for commercialization and, therefore, needs additional research and new approaches to affect lower installed costs. The two largest VAWTs -- 500 kW and 1.6 MW -- offer considerable promise for the most cost-effective electricity generation for electric utilities and, therefore, are most appropriate for a full scale research and development program to turn the system configuration and point design concepts into demonstratably effective technology.

Because of the new concepts introduced in the 500 kW and 1.6 MW size VAWTs many of the component and subsystem choices for cost estimating were made without confidence in their ability to perform reliably. Therefore, although there is considerable confidence in the performance expectations and costs of the 10, 30, 120 and 200 kW units, the data for the two larger turbines must be considered preliminary and in need of confirmation by additional research, development and prototype activity.

SANVAWT, INC.
VAWT AND ENERGY COST SUMMARIES

SCENARIO (#)	SELLING PRICE ($)	INSTALLED COST ($)	ENERGY COST (¢)
	2718 - 5, 9 and 16 kW		
2a	10,710	16,530	6.6 - 35.0
2b	9,322	14,343	5.7 - 30.4
2c	8,370	12,592	5.0 - 26.7
2d	7,519	10,521	4.2 - 22.3
	4530 - 18, 30 and 50 kW		
2a	16,950	25,468	2.9 - 15.2
2b	14,830	22,098	2.5 - 13.2
2c	13,215	19,316	2.2 - 11.5
2d	12,030	16,983	1.9 - 10.1
	8355 - 80, 120 and 210 kW		
1a	66,978	97,478	2.4 - 12.9
1b	60,000	90,500	2.3 - 12.0
1c	53,875	84,375	2.1 - 11.2
1d	50,000	80,500	2.0 - 10.7
2a	62,700	97,998	2.4 - 13.0
2b	53,672	81,973	2.0 - 10.8
2c	48,990	76,099	1.9 - 10.1
2d	45,113	67,874	1.7 - 9.0
	11375 - 135, 220 and 390 kW		
1a	124,075	170,575	2.3 - 11.6
1b	110,000	156,000	2.1 - 10.6
1c	99,000	145,500	2.0 - 9.9
1d	90,000	136,500	1.8 - 9.3
2a	113,750	172,800	2.3 - 11.8
2b	98,870	149,405	2.0 - 10.1
2c	88,950	133,153	1.7 - 9.0
2d	81,454	118,349	1.6 - 8.0
	150100 - 285, 480 and 935 kW		
1a	279,330	364,330	2.2 - 11.4
1b	250,000	335,000	2.0 - 10.5
1c	225,000	310,000	1.9 - 9.7
1d	210,000	295,000	1.8 - 9.3
	225150 - 935, 1600 and 2700 kW		
1a	831,190	1,039,190	2.2 - 11.2
1b	750,000	958,000	2.0 - 10.3
1c	675,000	883,000	1.9 - 9.5
1d	550,000	758,000	1.6 - 8.2

COST SUMMARY - SCENARIO #1a

COST ELEMENT	VAWT CAPACITY															
	14 Units - 120 kW				12 Units - 200 kW				5 Units - 500 kW				2 Units - 1600 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	40,870	41.9*	25,383	100	75,710	44.4*	46,776	100	170,450	46.8*	107,958	100	507,190	48.8*	307,233	100
Rotor Blades	9,770	23.9	5,147	20.3	16,000	21.1	8,592	18.4	27,000	15.9	18,478	17.1	102,000	20.1	47,082	15.3
Rotor Tower	5,000	12.2	7,854	30.9	13,200	17.4	14,216	30.4	34,500	20.3	34,920	32.3	101,000	19.9	107,830	35.1
Tiedowns	2,500	6.1	2,493	9.8	6,000	7.9	6,283	13.4	14,000	8.2	12,639	11.7	40,000	7.9	37,931	12.4
Drive Train	16,500	40.4	7,129	28.1	26,000	34.4	13,215	28.3	58,000	34.0	31,341	29.1	200,000	39.5	90,480	29.4
Electricals	6,500	15.9	2,310	9.1	13,000	17.2	3,620	7.7	34,000	19.9	8,760	8.1	55,000	10.8	19,670	6.4
Miscellaneous	600	1.5	450	1.8	1,500	2.0	850	1.8	2,950	1.7	1,820	1.7	9,190	1.8	4,240	1.4
Production Overhead	7,900	8.1			14,630	8.6			32,940	9.0			98,000	9.4		
Corporate Overhead	9,170	9.4			16,995	10.0			38,240	10.5			113,800	11.0		
Profit	9,038	9.3			16,740	9.8			37,700	10.3			112,200	10.8		
Typical Delivery	500	0.5			1,500	0.9			3,000	0.8			8,000	0.8		
Typical On-Site	30,000	30.8			45,000	26.4			82,000	22.5			200,000	19.2		
Installed Cost	97,478	100			170,575	100			364,330	100			1,039,190	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 15 mph	.047				.042				.041				.042			
@ 18 mph	.024				.023				.022				.022			
15% Annualized																
@ 15 mph	.058				.052				.051				.052			
@ 18 mph	.030				.029				.028				.028			
18% Annualized																
@ 15 mph	.070				.062				.061				.062			
@ 18 mph	.037				.034				.033				.033			

COST SUMMARY - SCENARIO #1b

COST ELEMENT	VAWT CAPACITY															
	30 Units - 120 kW				24 Units - 200 kW				10 Units - 500 kW				4 Units - 1600 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	39,700	43.9*	25,383	100	72,600	46.4*	46,776	100	165,000	49.3*	107,958	100	495,000	51.7*	307,233	100
Rotor Blades	9,600	24.2	5,147	20.3	15,500	21.3	8,592	18.4	25,200	15.3	18,478	17.1	98,000	19.8	47,082	15.3
Rotor Tower	4,800	12.1	7,854	30.9	12,500	17.2	14,216	30.4	33,000	20.0	34,920	32.3	97,500	19.7	107,830	35.1
Tiedowns	2,500	6.3	2,493	9.8	6,000	8.3	6,283	13.4	14,000	8.5	12,639	11.7	40,000	8.1	37,931	12.4
Drive Train	16,000	40.3	7,129	28.1	25,000	34.4	13,215	28.3	57,000	34.5	31,341	29.1	197,500	39.9	90,480	29.4
Electricals	6,200	15.6	2,310	9.1	12,400	17.1	3,620	7.7	33,000	20.0	8,760	8.1	53,000	10.7	19,670	6.4
Miscellaneous	600	1.5	450	1.8	1,200	1.7	850	1.8	2,800	1.7	1,820	1.7	9,000	1.8	4,240	1.4
Production Overhead	6,600	7.3			12,210	7.8			27,750	8.3			83,250	8.7		
Corporate Overhead	6,600	7.3			12,210	7.8			27,750	8.3			83,250	8.7		
Profit	7,100	7.8			12,980	8.3			29,500	8.8			88,500	9.2		
Typical Delivery	500	0.6			1,500	1.0			3,000	0.9			8,000	0.8		
Typical On-Site	30,000	33.1			45,000	28.7			82,000	24.5			200,000	20.9		
Installed Cost	90,500	100			156,500	100			335,000	100			958,000	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 15 mph	.043				.038				.037				.038			
@ 18 mph	.023				.021				.020				.020			
15% Annualized																
@ 15 mph	.054				.048				.047				.048			
@ 18 mph	.028				.026				.025				.025			
18% Annualized																
@ 15 mph	.065				.057				.056				.057			
@ 18 mph	.034				.031				.030				.031			

* Individual Items Within Subsystems and Components Add to 100%

COST SUMMARY - SCENARIO #1c

COST ELEMENT	VAWT CAPACITY															
	88 Units - 120 kW				66 Units - 200 kW				28 Units - 500 kW				11 Units - 1600 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	37,713	44.7*	25,383	100	69,300	47.6*	46,776	100	157,500	50.8*	107,958	100	472,500	53.5*	307,233	100
Rotor Blades	8,180	21.7	5,147	20.3	14,740	21.3	8,592	18.4	23,800	15.1	18,478	17.1	97,000	20.6	47,082	15.3
Rotor Tower	4,183	11.1	7,854	30.9	12,160	17.5	14,216	30.4	30,490	19.4	34,920	32.3	96,000	20.3	107,830	35.1
Tiedowns	2,400	6.4	2,493	9.8	5,500	7.9	6,283	13.4	14,000	8.9	12,639	11.7	40,000	8.5	37,931	12.4
Drive Train	16,200	43.0	7,129	28.1	25,500	36.8	13,215	28.3	55,410	35.2	31,341	29.1	177,500	37.6	90,480	29.4
Electricals	6,200	16.4	2,310	9.1	10,000	14.4	3,620	7.7	31,000	19.7	8,760	8.1	53,000	11.2	19,670	6.4
Miscellaneous	550	1.5	450	1.8	1,400	2.0	850	1.8	2,800	1.8	1,820	1.7	9,000	1.9	4,240	1.4
Production Overhead	5,226	6.2	9,603	6.6	9,603	6.6			21,825	7.0			65,475	7.4		
Corporate Overhead	4,471	5.3			8,217	5.6			18,675	6.0			56,025	6.3		
Profit	6,465	7.7			11,880	8.2			27,000	8.7			81,000	9.2		
Typical Delivery	500	0.6			1,500	1.0			3,000	1.0			8,000	0.9		
Typical On-Site	30,000	35.6			45,000	30.9			82,000	26.5			200,000	22.7		
Installed Cost	84,375	100			145,500	100			310,000	100			883,000	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 15 mph		.040				.035				.035				.035		
@ 18 mph		.021				.020				.019				.019		
15% Annualized																
@ 15 mph		.051				.044				.043				.044		
@ 18 mph		.026				.025				.023				.023		
18% Annualized																
@ 15 mph		.061				.053				.052				.053		
@ 18 mph		.032				.029				.028				.028		

COST SUMMARY - SCENARIO #1d

COST ELEMENT	VAWT CAPACITY															
	192 Units - 120 kW				149 Units - 200 kW				63 Units - 500 kW				25 Units - 1600 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	36,900	45.8*	25,383	100	66,420	48.7*	46,776	100	154,980	52.5*	107,958	100	405,900	53.5*	307,233	100
Rotor Blades	8,110	22.0	5,147	20.3	14,000	21.1	8,592	18.4	23,300	15.0	18,478	17.1	90,000	22.2	47,082	15.3
Rotor Tower	4,150	11.2	7,854	30.9	11,570	17.4	14,216	30.4	29,880	19.3	34,920	32.3	88,000	21.7	107,830	35.1
Tiedowns	2,300	6.2	2,493	9.8	5,500	8.3	6,283	13.4	14,000	9.0	12,639	11.7	38,000	9.4	37,931	12.4
Drive Train	15,800	42.8	7,129	28.1	24,500	36.9	13,215	28.3	54,500	35.2	31,341	29.1	136,900	33.7	90,480	29.4
Electricals	6,000	16.3	2,310	9.1	9,500	14.3	3,620	7.7	30,500	19.7	8,760	8.1	45,000	11.1	19,670	6.4
Miscellaneous	540	1.5	450	1.8	1,350	2.0	850	1.8	2,800	1.8	1,820	1.7	8,000	2.0	4,240	1.4
Production Overhead	3,950	4.9			7,110	5.2			16,590	5.6			43,450	5.7		
Corporate Overhead	3,950	4.9			7,110	5.2			16,590	5.6			43,450	5.7		
Profit	5,200	6.5			9,360	6.9			21,840	7.4			57,200	7.5		
Typical Delivery	500	0.6			1,500	1.1			3,000	1.0			8,000	1.1		
Typical On-Site	30,000	37.3			45,000	33.0			82,000	27.8			200,000	29.3		
Installed Cost	80,500	100			136,500	100			295,000	100			758,000	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 15 mph		.039				.033				.033				.030		
@ 18 mph		.020				.018				.018				.016		
15% Annualized																
@ 15 mph		.048				.042				.041				.038		
@ 18 mph		.025				.023				.022				.020		
18% Annualized																
@ 15 mph		.058				.050				.050				.045		
@ 18 mph		.030				.028				.027				.024		

* Individual Items Within Subsystems and Components Add to 100%

COST SUMMARY - SCENARIO # 2a

COST ELEMENT	VAWT CAPACITY															
	180 Units - 10 kW				85 Units - 30 kW				20 Units - 120 kW				8 Units - 200 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	7,001	42.4*	3,822	100	11,082	43.5*	8,417	100	40,984	41.8*	25,383	100	74,370	43.0*	46,776	100
Rotor Blades	660	9.4	154	4.0	1,695	15.3	960	11.4	9,800	23.9	5,147	20.3	15,500	20.8	8,592	18.4
Rotor Tower	1,950	27.9	839	22.0	2,635	23.8	3,364	40.0	5,000	12.2	7,854	30.9	12,500	16.8	14,216	30.4
Tiedowns	550	7.9	181	4.7	1,190	10.7	557	6.6	2,500	6.1	2,493	9.8	6,100	8.2	6,283	13.4
Drive Train	2,400	34.3	1,718	45.0	3,810	34.4	2,271	27.0	16,500	40.3	7,129	28.1	26,000	35.0	13,215	28.3
Electricals	1,315	18.7	870	22.8	1,520	13.7	1,120	13.3	6,500	15.9	2,310	9.1	13,000	17.5	3,620	7.7
Miscellaneous	126	1.8	60	1.5	232	2.1	145	1.7	684	1.7	450	1.8	1,270	1.7	850	1.8
Production Overhead	1,306	7.9			2,067	8.1			7,644	7.8			13,871	8.0		
Corporate Overhead	1,235	7.5			1,956	7.7			7,232	7.4			13,124	7.6		
Profit	1,168	7.1			1,845	7.2			6,840	7.0			12,385	7.2		
State/Local Taxes	428	2.6			678	2.7			2,508	2.6			4,550	2.6		
Distribution	2,142	13.0			3,390	13.3			12,540	12.8			22,750	13.2		
Delivery	250	1.5			250	1.0			250	0.3			750	0.4		
On-Site	3,000	18.1			4,200	16.5			20,000	20.4			31,000	17.9		
Installed Cost	16,530	100			25,468	100			97,998	100			172,800	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 12 mph		.233				.101				.086				.078		
@ 15 mph		.121				.051				.047				.042		
@ 18 mph		.066				.029				.024				.023		
15% Annualized																
@ 12 mph		.292				.127				.108				.098		
@ 15 mph		.151				.064				.059				.053		
@ 18 mph		.082				.036				.031				.292		

COST SUMMARY - SCENARIO # 2b

COST ELEMENT	VAWT CAPACITY															
	322 Units - 10 kW				180 Units - 30 kW				40 Units - 120 kW				22 Units - 200 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	6,600	46.0*	3,822	100	10,500	47.5*	8,417	100	38,000	46.4*	25,383	100	70,000	46.9*	46,776	100
Rotor Blades	580	8.8	154	4.0	1,560	14.9	960	11.4	9,130	24.0	5,147	20.3	14,800	21.1	8,592	18.4
Rotor Tower	1,600	25.2	839	22.0	2,360	22.5	3,364	40.0	4,590	12.1	7,854	30.9	11,700	16.7	14,216	30.4
Tiedowns	540	8.2	181	4.7	1,150	11.0	557	6.6	2,400	6.3	2,493	9.8	5,800	8.3	6,283	13.4
Drive Train	2,390	36.2	1,718	45.0	3,700	35.2	2,271	27.0	15,400	40.5	7,129	28.1	25,500	36.4	13,215	28.3
Electricals	1,310	19.8	870	22.8	1,500	14.3	1,120	13.3	5,900	15.5	2,310	9.1	11,000	14.3	3,620	7.7
Miscellaneous	120	1.8	60	1.5	230	2.2	145	1.7	580	1.5	450	1.8	1,200	1.7	850	1.8
Production Overhead	1,035	7.2			1,646	7.4			5,958	7.3			10,975	7.3		
Corporate Overhead	755	5.3			1,201	5.4			4,347	5.3			8,008	5.4		
Profit	932	6.5			1,483	6.7			5,367	6.5			9,887	6.6		
State/Local Taxes	373	2.6			593	2.7			2,147	2.6			3,955	2.6		
Distribution	1,398	9.7			2,225	10.1			8,051	9.8			14,830	9.9		
Delivery	250	1.7			250	1.1			250	0.3			750	0.5		
On-Site	3,000	20.9			4,200	19.0			20,000	24.4			31,000	20.7		
Installed Cost	14,343	100			22,098	100			81,973	100			149,405	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 12 mph		.203				.088				.072				.068		
@ 15 mph		.105				.044				.039				.036		
@ 18 mph		.057				.025				.020				.020		
15% Annualized																
@ 12 mph		.254				.110				.090				.085		
@ 15 mph		.131				.055				.049				.045		
@ 18 mph		.071				.032				.026				.025		

* Individual Items Within Subsystems and Components Add to 100%

COST SUMMARY - SCENARIO # 2c

COST ELEMENT	VAWT CAPACITY															
	1,000 Units - 10 kW				500 Units - 30 kW				100 Units - 120 kW				50 Units - 200 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	6,395	50.8*	3,822	100	10,096	52.3*	8,417	100	37,428	49.2*	25,383	100	67,958	51.0*	46,776	100
Rotor Blades	600	9.4	154	4.0	1,526	15.1	960	11.4	8,150	21.8	5,147	20.3	14,400	21.2	8,592	18.4
Rotor Tower	1,785	27.9	839	22.0	2,400	23.8	3,364	40.0	4,150	11.1	7,854	30.9	11,700	17.2	14,216	30.4
Tiedowns	500	7.8	181	4.7	1,100	10.9	557	6.6	2,400	6.4	2,493	9.8	5,500	8.1	6,283	13.4
Drive Train	2,190	34.2	1,718	45.0	3,470	34.4	2,271	27.0	16,200	43.3	7,129	28.1	25,500	37.5	13,215	28.3
Electricals	1,200	18.8	870	22.8	1,400	13.9	1,120	13.3	6,100	16.3	2,310	9.1	9,500	14.0	3,620	7.7
Miscellaneous	120	1.9	60	1.5	200	2.0	145	1.7	428	1.1	450	1.8	1,358	2.0	850	1.8
Production Overhead	812	6.4			1,282	6.6			4,752	6.2			8,628	6.5		
Corporate Overhead	494	3.9			780	4.0			2,890	3.8			5,248	3.9		
Profit	670	5.3			1,057	5.5			3,919	5.1			7,116	5.3		
State/Local Taxes	335	2.7			528	2.7			1,960	2.6			3,558	2.7		
Distribution	837	6.6			1,322	6.8			4,899	6.4			8,895	6.7		
Delivery	250	2.0			250	1.3			250	0.3			750	0.6		
On-Site	2,800	22.2			4,000	20.7			20,000	26.3			31,000	23.3		
Installed Cost	12,592	100			19,316	100			76,099	100			133,153	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 12 mph	.178				.077				.067				.060			
@ 15 mph	.092				.039				.037				.032			
@ 18 mph	.050				.022				.019				.017			
15% Annualized																
@ 12 mph	.223				.096				.084				.075			
@ 15 mph	.115				.048				.046				.040			
@ 18 mph	.063				.028				.024				.022			

COST SUMMARY - SCENARIO # 2d

COST ELEMENT	VAWT CAPACITY															
	2,140 Units - 10 kW				1,000 Units - 30 kW				250 Units - 120 kW				130 Units - 200 kW			
	Cost		Weight		Cost		Weight		Cost		Weight		Cost		Weight	
	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%	$	%	Pounds	%
Subsystems/ Components:	6,000	57.0*	3,822	100	9,600	56.5*	8,417	100	36,000	53.0*	25,383	100	65,000	54.9*	46,776	100
Rotor Blades	580	9.7	154	4.0	1,500	15.6	960	11.4	8,000	22.2	5,147	20.3	13,600	20.9	8,592	18.4
Rotor Tower	1,485	24.8	839	22.0	2,100	21.9	3,364	40.0	3,836	10.7	7,854	30.9	11,200	17.2	14,216	30.4
Tiedowns	500	8.3	181	4.7	1,100	11.5	557	6.6	2,300	6.4	2,493	9.8	5,500	8.5	6,283	13.4
Drive Train	2,160	36.0	1,718	45.0	3,430	35.7	2,271	27.0	15,800	43.9	7,129	28.1	24,050	37.0	13,215	28.3
Electricals	1,165	19.4	870	22.8	1,290	13.4	1,120	13.3	5,639	15.7	2,310	9.1	9,300	14.3	3,620	7.7
Miscellaneous	110	1.8	60	1.5	180	1.9	145	1.7	425	1.2	450	1.8	1,350	2.1	850	1.8
Production Overhead	594	5.6			950	5.6			3,564	5.3			6,435	5.4		
Corporate Overhead	383	3.6			614	3.6			2,301	3.4			4,154	3.5		
Profit	541	5.1			866	5.1			3,248	4.8			5,865	5.0		
State/Local Taxes	301	2.9			481	2.8			1,805	2.7			3,258	2.8		
Distribution	451	4.3			722	4.3			2,707	4.0			4,887	4.1		
Delivery	250	2.4			250	1.5			250	0.4			750	0.6		
On-Site	2,000	19.0			3,500	20.6			18,000	26.5			28,000	23.7		
Installed Cost	10,521	100			16,983	100			67,874	100			118,349	100		
Energy Cost ($/kWh):																
12% Annualized																
@ 12 mph	.149				.067				.060				.054			
@ 15 mph	.077				.034				.033				.029			
@ 18 mph	.042				.019				.017				.016			
15% Annualized																
@ 12 mph	.186				.084				.075				.067			
@ 15 mph	.096				.042				.041				.036			
@ 18 mph	.052				.024				.021				.020			

* Individual Items Within Subsystems and Components Add to 100%

SANVAWT, INC.
Business Scenario #1

Business Objective: Profitably serve the region's electricity-generating utilities with medium-to-large capacity (100 kW and up) Vertical Axis Wind Turbines for integration into those utilities' generation stations.

Factory Functions:

Purchase materials needed for in-plant fabrication and fabricate specific components.

Purchase some fabricated components for in-plant assembly or collection for coordinated delivery.

Assemble fabricated and purchased components into manageable subassemblies and subsystems.

Implement quality control program to assure adequacy and fit of all subsystems.

Package, store and load all subassemblies and individual components for shipment.

Marketing Functions:

Define and price line of standard VAWTs offered for sale.

Prepare necessary advertising and promotion programs to interest utilities in SANVAWT systems.

Provide engineering assistance to utilities in specifying VAWTs.

Solicit orders for purchase of standard SANVAWT VAWTs.

Administer execution of the terms and conditions of the sales when orders are received.

Arrange logistics of production, delivery, staging and erection of the VAWTs in conjunction with the utility and its erection contractor.

Delivery Functions:

Deliver the VAWT subsystems, without damage, to the appropriate site's staging area by means of truck.

On-Site Functions:

Unload, collect and account for all delivered subsystems and components, and store them in a protected, retrievable manner at the installation site.

Prepare the site for assembly and erection of the VAWT by building necessary base foundations and tie-down footings.

On-Site Functions: (continued)

Assemble and erect the VAWTs and excecute necessary interface connections with the generating station.

Start up the VAWTs to assure successful operation and make necessary corrections and modifications.

Train the utility's operating and maintenance personnel in procedures needed for successful functioning of the turbines and turn over operating, service and warranty data.

Monitor operations and provide appropriate service during the warranty period.

Product Line Summary:

VAWT Designation	Height/Diameter (Feet)	Wind Regime (mph)	Rated Power (kW)	Annual Energy (kWh)
8355-80	83 x 55	12	80	136,000
8355-120	83 x 55	15	120	250,000
8355-210	83 x 55	18	210	480,000
11375-135	113 x 75	12	135	265,000
11375-220	113 x 75	15	220	493,000
11375-390	113 x 75	18	390	890,000
150100-285	150 x 100	12	285	574,000
150100-480	150 x 100	15	480	1,070,000
150100-935	150 x 100	18	935	1,980,000
225150-935	225 x 150	12	935	1,670,000
225150-1600	225 x 150	15	1600	3,000,000
225150-2700	225 x 150	18	2700	5,640,000

Facility and People Requirements:

	Scenario			
	#1a	#1b	#1c	#1d
Production Space (S.F.)	30,000	30,000	70,000	110,000
Office Space (S.F.)	4,500	4,500	9,500	16,500
Personnel (No. People)	69	132	333	665
Management/Clerical	16	26	46	79
Marketing/Sales	2	4	5	8
Indirect Labor	5	9	22	39
Direct Labor	46	93	260	539

SANVAWT, INC. (Business Scenario #1a)

Mission: Fabricate, sell and service standard Vertical Axis Wind Turbines for electricity generating utilities within 500 miles of the SANVAWT plant.

Product Line: 120 kW, 200 kW, 500 kW and 1.6 MW VAWTs with appropriate accessories.

Basic Company: A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.

Sales Goals: A product mix of the four sizes of turbines that will result in delivery of 10 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs are assumed, as is the production capability of the plant. The annual plant revenue, in 1978 dollars, is projected at $5.5 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Direct Labor & Material Costs	$40,870	$ 75,710	$170,450	$507,190
Production Overhead	7,900	14,630	32,940	98,000
Corporate Overhead	9,170	16,995	38,240	113,800
Profit	9,038	16,740	37,700	112,200
Selling Price (F.O.B. Plant):	$66,978	$124,075	$279,330	$831,190
Estimated Delivery (250 mile average):	$ 500	$ 1,500	$ 3,000	$ 8,000
Delivered Cost:	$67,478	$125,575	$282,330	$839,190
On-Site Costs:				
Site Preparation & Foundations	$16,000	$ 25,000	$ 45,000	$133,000
Assembly/Erection	14,000	20,000	37,000	67,000
	$30,000	$ 45,000	$ 82,000	$200,000
Installed Costs:	$97,478	$170,575	$364,330	$1,039,190

SANVAWT, INC. (Business Scenario #1a)

Costs to the Utility:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Installed Cost ($):	97,478	170,575	364,330	1,039,190
Ownership Cost ($):				
Annualized @				
12%	11,700	20,472	43,740	124,800
15%	14,625	25,590	54,675	156,000
18%	17,550	30,708	65,610	187,200
Annual Energy:				
kWh @				
12 mph mean	136,000	265,000	574,000	1,670,000
15 mph mean	250,000	493,000	1,070,000	3,000,000
18 mph mean	480,000	890,000	1,980,000	5,640,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.086	.077	.076	.075
15 mph	.047	.042	.041	.042
18 mph	.024	.023	.022	.022
15% Annualized				
12 mph	.108	.097	.095	.093
15 mph	.058	.052	.051	.052
18 mph	.030	.029	.028	.028
18% Annualized				
12 mph	.129	.116	.114	.112
15 mph	.070	.062	.061	.062
18 mph	.037	.034	.033	.033

SANVAWT, INC. (Scenario #1a)
Corporate Financial Plan
10 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$ 5,490
Cost of Goods Sold:		
Direct Labor and Material	$ 3,350	
Production Overhead	650	
Total		$ 4,000
Corporate Overhead:		
Interest on Borrowed Capital	$ 250	
Sales and Administrative Expense	500	
Total		$ 750
Profit (Loss) Before Federal Taxes		$ 740
Capital in Use:		
Accounts Receivable - 60 Days	$ 825	
Inventory	625	
Fixed Capital	400	
Total	$ 1,850	
Return on Capital in Use	40.0%	

10 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
120 kW	14	1,680 kW
200 kW	12	2,640 kW
500 kW	5	2,400 kW
1600 kW	2	3,200 kW
Totals	33	9,920 kW

SANVAWT, INC. (Scenario #1a)
10 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - Seven People	$ 156,800
Other Payroll Costs @ 30%	47,000
Office Rent - 2,500 Square Feet	12,500
Telephone and Telegraph	35,000
Office Supplies and Postage	12,000
Printing and Photocopy	6,000
Travel and Per Diem Expense	40,000
Entertainment	7,200
Public Relations and Advertising	50,000
Legal Expense	20,000
Technology Development	50,000
Employee Relocation Allowance	20,000
Uncollectable Accounts - .75% of Sales	37,500
State and Local Corporate Taxes	6,000
Interest	250,000
Total Corporate Overhead	$ 750,000
Corporate Overhead/Revenue	13.7%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 11 People (Mgt. and Clerical)	$ 199,000
Other Payroll Costs @ 30%	60,000
Plant Rental - 32,000 Square Feet	50,000
Depreciation and Rental of Tools/Equipment	100,000
Insurance	7,500
Office Supplies and Production Travel	18,000
Repairs and Maintenance	50,000
Utilities	28,000
Telephone and Telegraph	8,000
Indirect Labor	38,000
Shop Supplies	24,000
Business Fees and Transportation Permits	2,500
Quality Assurance	15,000
Warranty Service @ 1% of Sales	50,000
Total Production Overhead	$ 650,000
Production Overhead/Revenue	11.8%

SANVAWT, INC. (Scenario #1a)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(14 Units/Year)

VAWT Description:		
Peak Electrical Capacity	120 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	28.5 kW	
Annual Energy Output @ 15 mph Site	250,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 9,770	
Rotor Tower	5,000	
Tiedowns	2,500	
Transmission and Drive Train	16,500	
Electricals	6,500	
Miscellaneous	600	
Direct Cost		$ 40,870
Production Overhead @ 11.8%		$ 7,900
Corporate Overhead @ 13.7%		9,170
Profit @ 13.5%		9,038
Selling Price (F.O.B. Plant):		$ 66,978
Typical Delivery Cost		$ 500
Typical On-Site Costs		30,000
Estimated Installed Cost to Owner		$ 97,478

SANVAWT, INC. (Scenario #1a)
ON-SITE WORK
120 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 16,000
(2) Fencing, Environmental Covers and Subsystem Erection	14,000
Total On-Site Costs	$ 30,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 mi.	$500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1a)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(12 Units/Year)

VAWT Description:		
Peak Electrical Capacity	220 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	56.3 kW	
Annual Energy Output @ 15 mph Site	493,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 16,000	
Rotor Tower	13,200	
Tiedowns	6,000	
Transmission and Drive Train	26,000	
Electricals	13,000	
Miscellaneous	1,510	
Direct Cost		$ 75,710
Production Overhead @ 11.8%		$ 14,630
Corporate Overhead @ 13.7%		16,995
Profit @ 13.5%		16,740
Selling Price (F.O.B. Plant):		$ 124,075
Typical Delivery Cost		$ 1,500
Typical On-Site Costs		45,000
Estimated Installed Cost to Owner		$ 170,575

SANVAWT, INC. (Scenario #1a)
ON-SITE WORK
200 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 24,500
(2) Fencing, Environmental Covers and Subsystem Erection	20,500
Total On-Site Costs	$ 45,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 mi.	$1,500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1a)
Cost Estimate and Selling Price
500 kW Vertical Axis Wind Turbine

(5 Units/Year)

VAWT Description:		
Peak Electrical Capacity	480 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	122.1 kW	
Annual Energy Output @ 15 mph Site	1,070,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 27,000	
Rotor Tower	34,500	
Tiedowns	14,000	
Transmission and Drive Train	58,000	
Electricals	34,000	
Miscellaneous	2,950	
Direct Cost		$ 170,450
Production Overhead @ 11.8%		$ 32,940
Corporate Overhead @ 13.7%		38,240
Profit @ 13.5%		37,700
Selling Price (F.O.B. Plant):		$ 279,330
Typical Delivery Cost		$ 3,000
Typical On-Site Costs		82,000
Estimated Installed Cost to Owner		$ 364,330

SANVAWT, INC. (Scenario #1a)
ON-SITE WORK
500 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 45,000
(2) Fencing, Environmental Covers and Subsystem Erection	37,000
Total On-Site Costs	$ 82,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
500 kW	101,622#	5 @ 250 mi.	$3,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1a)
Cost Estimate and Selling Price
1.6 MW Vertical Axis Wind Turbine

(2 Units/Year)

VAWT Description:		
Peak Electrical Capacity	1,600 kW	
Wind Velocity @ Peak Capacity	31 mph	
Average Electrical Output @ 15 mph	342.5 kW	
Annual Energy Output @ 15 mph Site	3,000,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 102,000	
Rotor Tower	101,000	
Tiedowns	40,000	
Transmission and Drive Train	200,000	
Electricals	55,000	
Miscellaneous	9,190	
Direct Cost		$ 507,190
Production Overhead @ 11.8%		$ 98,000
Corporate Overhead @ 13.7%		113,800
Profit @ 13.5%		112,200
Selling Price (F.O.B. Plant):		$ 831,190
Typical Delivery Cost		$ 8,000
Typical On-Site Costs		200,000
Estimated Installed Cost to Owner		$1,039,190

SANVAWT, INC. (Scenario #1a)
ON-SITE WORK
1.6 MW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$133,000
(2) Fencing, Environmental Covers and Subsystem Erection	67,000
Total On-Site Costs	$200,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
1.6 MW	235,830#	12 @ 250 mi.	$8,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Business Scenario #1b)

Mission: Fabricate, sell and service standard Vertical Axis Wind Turbines for electricity generating utilities within 500 miles of the SANVAWT plant.

Product Line: 120 kW, 200 kW, 500 kW and 1.6 MW VAWTs with appropriate accessories.

Basic Company: A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.

Sales Goals: A product mix of the four sizes of turbines that will result in delivery of 20 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs are assumed, as is the production capability of the plant. At an average fair market plant value of the VAWTs projected as $500 per peak kW, the annual plant revenue, in 1978 dollars, is projected at $10 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Direct Labor and Material Costs	$39,700	$ 72,600	$165,000	$495,000
Production Overhead	6,600	12,210	27,750	83,250
Corporate Overhead	6,600	12,210	27,750	83,250
Profit	7,100	12,980	29,500	88,500
Selling Price (F.O.B. Plant)	$60,000	$110,000	$250,000	$750,000
Estimated Delivery (250 mile average):	$ 500	$ 1,500	$ 3,000	$ 8,000
Delivered Cost:	$60,500	$111,500	$253,000	$758,000
On-Site Costs:				
Site Preparation & Foundations	$16,000	$ 25,000	$ 45,000	$133,000
Assembly/Erection	14,000	20,000	37,000	67,000
	$30,000	$ 45,000	$ 82,000	$200,000
Installed Costs:	$90,500	$156,500	$335,000	$958,000

SANVAWT, INC. (Business Scenario #1b)

Costs to the Utility:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Installed Cost ($):	90,500	156,500	335,000	958,000
Ownership Cost ($):				
Annualized @				
12%	10,860	18,780	40,200	114,960
15%	13,575	23,475	50,250	143,700
18%	16,290	28,170	60,300	172,440
Annual Energy:				
kWh @				
12 mph mean	136,000	265,000	574,000	1,670,000
15 mph mean	250,000	493,000	1,070,000	3,000,000
18 mph mean	480,000	890,000	1,980,000	5,640,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.080	.071	.070	.069
15 mph	.043	.038	.037	.038
18 mph	.023	.021	.020	.020
15% Annualized				
12 mph	.100	.089	.088	.086
15 mph	.054	.048	.047	.048
18 mph	.028	.026	.025	.025
18% Annualized				
12 mph	.120	.106	.105	.103
15 mph	.065	.057	.056	.057
18 mph	.034	.031	.030	.031

SANVAWT, INC. (Scenario #1b)
Corporate Financial Plan
20 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$10,000
Cost of Goods Sold:		
Direct Labor and Material	$6,602	
Production Overhead	1,111	
Total		$ 7,713
Corporate Overhead:		
Interest on Borrowed Capital	$ 380	
Sales and Administrative Expense	727	
Total		$ 1,107
Profit (Loss) Before Federal Taxes		$ 1,180
Capital in Use:		
Accounts Receivable - 58 Days	$1,590	
Inventory	860	
Fixed Capital	500	
Total	$2,950	
Return on Capital in Use	40.0%	

20 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
120 kW	30	3,600 kW
200 kW	24	5,280 kW
500 kW	10	4,800 kW
1600 kW	4	6,400 kW
Totals	68	20,080 kW

SANVAWT, INC. (Scenario #1b)
20 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - 11 People	$ 220,000
Other Payroll Costs @ 30%	66,000
Office Rent - 3,000 Square Feet	15,000
Telephone and Telegraph	50,000
Office Supplies and Postage	16,000
Printing and Photocopy	8,000
Travel and Per Diem Expense	60,000
Entertainment	10,000
Public Relations and Advertising	70,000
Legal Expense	30,000
Technology Development	60,000
Employee Relocation Allowance	35,000
Uncollectable Accounts - .75% of Sales	75,000
State and Local Corporate Taxes	12,000
Interest	380,000
Total Corporate Overhead	$1,107,000
Corporate Overhead/Revenue	11.1%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 19 People (Mgt. and Clerical)	$ 332,000
Other Payroll Costs @ 30%	99,600
Plant Rental - 32,000 Square Feet	50,000
Depreciation and Rental of Tools/Equipment	140,000
Insurance	12,000
Office Supplies and Production Travel	18,000
Repairs and Maintenance	75,000
Utilities	45,000
Telephone and Telegraph	11,000
Indirect Labor	73,000
Shop Supplies	40,000
Business Fees and Transportation Permits	5,000
Quality Assurance	30,000
Warranty Service @ 1% of Sales	100,000
Shift Premium @ 7% of Hourly Payroll	70,000
Total Production Overhead	$1,110,600
Production Overhead/Revenue	11.1%

SANVAWT, INC. (Scenario #1b)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(30 Units/Year)

VAWT Description:		
Peak Electrical Capacity	120 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	28.5 kW	
Annual Energy Output @ 15 mph site	250,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 9,600	
Rotor Tower	4,800	
Tiedowns	2,500	
Transmission and Drive Train	16,000	
Electricals	6,200	
Miscellaneous	600	
Direct Cost		$ 39,700
Production Overhead @ 11.1%		$ 6,600
Corporate Overhead @ 11.1%		6,600
Profit @ 11.8%		7,100
Selling Price (F.O.B. Plant):		$ 60,000
Typical Delivery Cost		$ 500
Typical On-Site Costs		30,000
Estimated Installed Cost to Owner		$ 90,500

SANVAWT, INC. (Scenario #1b)
ON-SITE WORK
120 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 16,000
(2) Fencing, Environmental Covers and Subsystem Erection	14,000
Total On-Site Costs	$ 30,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 mi.	$500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1b)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(24 Units/Year)

VAWT Description:

Peak Electrical Capacity	220 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	56.3 kW
Annual Energy Output @ 15 mph site	493,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$ 15,500	
Rotor Tower	12,500	
Tiedowns	6,000	
Transmission and Drive Train	25,000	
Electricals	12,400	
Miscellaneous	1,200	
Direct Cost		$ 72,600
Production Overhead @ 11.1%		$ 12,210
Corporate Overhead @ 11.1%		12,210
Profit @ 11.8%		12,980
Selling Price (F.O.B. Plant):		$110,000
Typical Delivery Cost		$ 1,500
Typical On-Site Costs		45,000
Estimated Installed Cost to Owner		$156,500

SANVAWT, INC. (Scenario #1b)
ON-SITE WORK
500 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 45,000
(2) Fencing, Environmental Covers and Subsystem Erection	37,000
Total On-Site Costs	$ 82,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
500 kW	101,622#	5 @ 250 mi.	$3,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1b)
Cost Estimate and Selling Price
500 kW Vertical Axis Wind Turbine

(10 Units/Year)

VAWT Description:		
Peak Electrical Capacity	480 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	122.1 kW	
Annual Energy Output @ 15 mph site	1,070,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 25,200	
Rotor Tower	33,000	
Tiedowns	14,000	
Transmission and Drive Train	57,000	
Electricals	33,000	
Miscellaneous	2,800	
Direct Cost		$165,000
Production Overhead @ 11.1%		$ 27,750
Corporate Overhead @ 11.1%		27,750
Profit @ 11.8%		29,500
Selling Price (F.O.B. Plant):		$250,000
Typical Delivery Cost		$ 3,000
Typical On-Site Costs		82,000
Estimated Installed Cost to Owner		$335,000

SANVAWT, INC. (Scenario #1b)
ON-SITE WORK
200 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 24,500
(2) Fencing, Environmental Covers and Subsystem Erection	20,500
Total On-Site Costs	$ 45,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 mi.	$1,500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1b)
Cost Estimate and Selling Price
1.6 MW Vertical Axis Wind Turbine

(4 Units/Year)

VAWT Description:		
Peak Electrical Capacity	1,600 kW	
Wind Velocity @ Peak Capacity	31 mph	
Average Electrical Output @ 15 mph	342.5 kW	
Annual Energy Output @ 15 mph site	3,000,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 98,000	
Rotor Tower	97,500	
Tiedowns	40,000	
Transmission and Drive Train	197,500	
Electricals	53,000	
Miscellaneous	9,000	
Direct Cost		$ 495,000
Production Overhead @ 11.1%		$ 83,250
Corporate Overhead @ 11.1%		83,250
Profit @ 11.8%		88,500
Selling Price (F.O.B. Plant):		$ 750,000
Typical Delivery Cost		$ 8,000
Typical On-Site Costs		200,000
Estimated Installed Cost to Owner		$ 958,000

SANVAWT, INC. (Scenario #1b)
ON-SITE WORK
1.6 MW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$133,000
(2) Fencing, Environmental Covers and Subsystem Erection	67,000
Total On-Site Costs	$200,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
1.6 MW	235,830#	12 @ 250 mi.	$8,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Business Scenario #1c)

Mission: Fabricate, sell and service standard Vertical Axis Wind Turbines for electricity generating utilities within 500 miles of the SANVAWT plant.

Product Line: 120 kW, 200 kW, 500 kW and 1.6 MW VAWTs with appropriate accessories.

Basic Company: A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.

Sales Goals: A product mix of the four sizes of turbines that will result in delivery of 56 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs are assumed, as is the production capability of the plant. The annual plant revenue, in 1978 dollars, is projected at $25 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Direct Labor and Material Costs	$37,713	$ 69,300	$157,500	$472,500
Production Overhead	5,226	9,603	21,825	65,475
Corporate Overhead	4,471	8,217	18,675	56,025
Profit	6,465	11,880	27,000	81,000
Selling Price (F.O.B. Plant):	$53,875	$ 99,000	$225,000	$675,000
Estimated Delivery (250 mile average):	$ 500	$ 1,500	$ 3,000	$ 8,000
Delivered Cost	$54,375	$100,500	$228,000	$683,000
On-Site Costs:				
Site Preparation & Foundations	$16,000	$ 25,000	$ 45,000	$133,000
Assembly/Erection	14,000	20,000	37,000	67,000
	$30,000	$ 45,000	$ 82,000	$200,000
Installed Costs:	$84,375	$145,500	$310,000	$883,000

SANVAWT, INC. (Business Scenario #1c)

Costs to the Utility:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Installed Cost ($):	84,375	145,500	310,000	883,000
Ownership Cost ($):				
Annualized @				
12%	10,125	17,460	37,200	105,960
15%	12,656	21,825	46,500	132,450
18%	15,188	26,190	55,800	158,940
Annual Energy:				
kWh @				
12 mph mean	136,000	265,000	574,000	1,670,000
15 mph mean	250,000	493,000	1,070,000	3,000,000
18 mph mean	480,000	890,000	1,980,000	5,640,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.074	.066	.065	.063
15 mph	.040	.035	.035	.035
18 mph	.021	.020	.019	.019
15% Annualized				
12 mph	.093	.082	.081	.079
15 mph	.051	.044	.043	.044
18 mph	.026	.025	.023	.023
18% Annualized				
12 mph	.112	.099	.097	.095
15 mph	.061	.053	.052	.053
18 mph	.032	.029	.028	.028

SANVAWT, INC. (Scenario #1c)
Corporate Financial Plan
56 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$25,000
Cost of Goods Sold:		
Direct Labor and Material	$17,500	
Production Overhead	2,425	
Total		$19,925
Corporate Overhead:		
Interest on Borrowed Capital	$ 750	
Sales and Administrative Expense	1,325	
Total		$ 2,075
Profit (Loss) Before Federal Taxes		$ 3,000
Capital in Use:		
Accounts Receivable - 58 Days	$ 4,000	
Inventory	2,500	
Fixed Capital	1,000	
Total	$ 7,500	
Return on Capital in Use	40.0%	

56 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
120 kW	88	10,560 kW
200 kW	66	14,520 kW
500 kW	28	13,440 kW
1600 kW	11	17,600 kW
Totals	193	56,136 kW

SANVAWT, INC. (Scenario #1c)
56 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - 16 People	$ 304,000
Other Payroll Costs @ 30%	91,000
Office Rent - 5,000 Square Feet	25,000
Telephone and Telegraph	70,000
Office Supplies and Postage	30,000
Printing and Photocopy	15,000
Travel and Per Diem Expense	100,000
Entertainment	20,000
Public Relations and Advertising	125,000
Legal Expense	50,000
Technology Development	200,000
Employee Relocation Allowance	75,000
Uncollectable Accounts - .75% of Sales	188,000
State and Local Corporate Taxes	20,000
Interest	750,000
Total Corporate Overhead	$2,063,000
Corporate Overhead/Revenue	8.3%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 35 People (Mgt. and Clerical)	$ 623,500
Other Payroll Costs @ 30%	186,750
Plant Rental - 74,500 Square Feet	117,000
Depreciation and Rental of Tools/Equipment	200,000
Insurance	21,000
Office Supplies and Production Travel	58,000
Repairs and Maintenance	160,000
Utilities	90,000
Telephone and Telegraph	20,000
Indirect Labor	175,000
Shop Supplies	90,000
Business Fees and Transportation Permits	12,000
Quality Assurance	88,000
Warranty Service @ 1% of Sales	250,000
Shift Premium @ 7% of Hourly Payroll	214,000
On-Line Computer Assistance	120,000
Total Production Overhead	$2,425,250
Production Overhead/Revenue	9.7%

SANVAWT, INC. (Scenario #1c)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(88 Units/Year)

VAWT Description:		
Peak Electrical Capacity	120 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	28.5 kW	
Annual Energy Output @ 15 mph site	250,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 8,180	
Rotor Tower	4,183	
Tiedowns	2,400	
Transmission and Drive Train	16,200	
Electricals	6,200	
Miscellaneous	550	
Direct Cost		$37,713
Production Overhead @ 9.7%		$ 5,226
Corporate Overhead @ 8.3%		4,471
Profit @ 12.0%		6,465
Selling Price (F.O.B. Plant):		$53,875
Typical Delivery Cost		$ 500
Typical On-Site Costs		30,000
Estimated Installed Cost to Owner		$84,375

SANVAWT, INC. (Scenario # 1c)
ON-SITE WORK
120 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 16,000
(2) Fencing, Environmental Covers and Subsystem Erection	14,000
Total On-Site Costs	$ 30,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 mi.	$500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1c)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(66 Units/Year)

VAWT Description:		
Peak Electrical Capacity	220 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	56.3 kW	
Annual Energy Output @ 15 mph site	493,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$14,740	
Rotor Tower	12,160	
Tiedowns	5,500	
Transmission and Drive Train	25,500	
Electricals	10,000	
Miscellaneous	1,400	
Direct Cost		$69,300
Production Overhead @ 9.7%		$ 9,603
Corporate Overhead @ 8.3%		8,217
Profit @ 12.0%		11,880
Selling Price (F.O.B. Plant):		$99,000
Typical Delivery Cost		$ 1,500
Typical On-Site Costs		45,000
Estimated Installed Cost to Owner		$145,500

SANVAWT, INC. (Scenario #1c)
ON-SITE WORK
200 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$24,500
(2) Fencing, Environmental Covers and Subsystem Erection	20,500
Total On-Site Costs	$45,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 mi.	$1,500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1c)
Cost Estimate and Selling Price
500 kW Vertical Axis Wind Turbine

(28 Units/Year)

VAWT Description:		
Peak Electrical Capacity	480 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	122.1 kW	
Annual Energy Output @ 15 mph site	1,070,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 23,800	
Rotor Tower	30,490	
Tiedowns	14,000	
Transmission and Drive Train	55,410	
Electricals	31,000	
Miscellaneous	2,800	
Direct Cost		$157,500
Production Overhead @ 9.7%		$ 21,825
Corporate Overhead @ 8.3%		18,675
Profit @ 12.0%		27,000
Selling Price (F.O.B. Plant):		$225,000
Typical Delivery Cost		$ 3,000
Typical On-Site Costs		82,000
Estimated Installed Cost to Owner		$310,000

SANVAWT, INC. (Scenario #1 c)
ON-SITE WORK
500 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$45,000
(2) Fencing, Environmental Covers and Subsystem Erection	37,000
Total On-Site Costs	$82,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
500 kW	101,622#	5 @ 250 mi.	$3,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1c)
Cost Estimate and Selling Price
1.6 MW Vertical Axis Wind Turbine

(11 Units/Year)

VAWT Description:		
Peak Electrical Capacity	1,600 kW	
Wind Velocity @ Peak Capacity	31 mph	
Average Electrical Output @ 15 mph	342.5 kW	
Annual Energy Output @ 15 mph site	3,000,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 97,000	
Rotor Tower	96,000	
Tiedowns	40,000	
Transmission and Drive Train	177,500	
Electricals	53,000	
Miscellaneous	9,000	
Direct Cost		$472,500
Production Overhead @ 9.7%		$ 65,475
Corporate Overhead @ 8.3%		56,025
Profit @ 12.0%		81,000
Selling Price (F.O.B. Plant):		$675,000
Typical Delivery Cost		$ 8,000
Typical On-Site Costs		200,000
Estimated Installed Cost to Owner		$883,000

SANVAWT, INC. (Scenario #1c)
ON-SITE WORK
1.6 MW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$133,000
(2) Fencing, Environmental Covers and Subsystem Erection	67,000
Total On-Site Costs	$200,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
1.6 MW	235,830#	12 @ 250 mi.	$8,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Business Scenario #1d)

Mission: Fabricate, sell and service standard Vertical Axis Wind Turbines for electricity generating utilities within 500 miles of the SANVAWT plant.

Product Line: 120 kW, 200 kW, 500 kW and 1.6 MW VAWTs with appropriate accessories.

Basic Company: A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.

Sales Goals: A product mix of the four sizes of turbines that will result in delivery of 126 megawatts of installed electricity generating peak capacity per year. Established markets for the quantity of VAWTs are assumed, as is the production capability of the plant. The annual plant revenue, in 1978 dollars, is projected at $50 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Direct Labor and Material Costs	$36,900	$ 66,420	$154,980	$405,900
Production Overhead	3,950	7,110	16,590	43,450
Corporate Overhead	3,950	7,110	16,590	43,450
Profit	5,200	9,360	21,840	57,200
Selling Price (F.O.B. Plant):	$50,000	$ 90,000	$210,000	$550,000
Estimated Delivery (250 mile average):	$ 500	$ 1,500	$ 3,000	$ 8,000
Delivered Cost:	$50,500	$ 91,500	$213,000	$558,000
On-Site Costs:				
Site Preparation & Foundations	$16,000	$ 25,000	$ 45,000	$133,000
Assembly/Erection	14,000	20,000	37,000	67,000
	$30,000	$ 45,000	$ 82,000	$200,000
Installed Costs:	$80,500	$136,500	$295,000	$758,000

SANVAWT, INC. (Business Scenario #1d)

Costs to the Utility:

	VAWT Capacity			
	120 kW	200 kW	500 kW	1.6 MW
Installed Cost ($):	80,500	136,500	295,000	758,000
Ownership Cost ($):				
Annualized @				
12%	9,660	16,380	35,400	90,960
15%	12,075	20,475	44,250	113,700
18%	14,490	24,570	53,100	136,440
Annual Energy:				
kWh @				
12 mph mean	136,000	265,000	574,000	1,670,000
15 mph mean	250,000	493,000	1,070,000	3,000,000
18 mph mean	480,000	890,000	1,980,000	5,640,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.071	.062	.062	.054
15 mph	.039	.033	.033	.030
18 mph	.020	.018	.018	.016
15% Annualized				
12 mph	.089	.077	.077	.068
15 mph	.048	.042	.041	.038
18 mph	.025	.023	.022	.020
18% Annualized				
12 mph	.107	.093	.093	.082
15 mph	.058	.050	.050	.045
18 mph	.030	.028	.027	.024

SANVAWT, INC. (Scenario #1d)
Corporate Financial Plan
126 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$50,000
Cost of Goods Sold:		
Direct Labor and Material	$36,900	
Production Overhead	3,950	
Total		$40,850
Corporate Overhead:		
Interest on Borrowed Capital	$ 1,300	
Sales and Administrative Expense	2,650	
Total		$ 3,950
Profit (Loss) Before Federal Taxes		$ 5,200
Capital in Use:		
Accounts Receivable - 51 Days	$ 7,000	
Inventory	4,500	
Fixed Capital	1,500	
Total	$13,000	
Return on Capital in Use	40%	

126 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
120 kW	192	23,040 kW
200 kW	149	32,780 kW
500 kW	63	30,240 kW
1600 kW	25	40,000 kW
Totals	429	126,060 kW

SANVAWT, INC. (Scenario #1d)
126 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - 25 People	$ 493,000
Other Payroll Costs @ 30%	148,000
Office Rent - 8,500 Square Feet	43,000
Telephone and Telegraph	120,000
Office Supplies and Postage	55,000
Printing and Photocopy	28,000
Travel and Per Diem Expense	200,000
Entertainment	50,000
Public Relations and Advertising	800,000
Legal Expense	90,000
Technology Development	500,000
Employee Relocation Allowance	120,000
Uncollectable Accounts - .75% of Sales	375,000
State and Local Corporate Taxes	35,000
Interest	1,300,000
Total Corporate Overhead	$4,357,000
Corporate Overhead/Revenue	7.9%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 62 People (Mgt. and Clerical)	$1,086,500
Other Payroll Costs @ 30%	326,000
Plant Rental - 118,000 Square Feet	189,000
Depreciation and Rental of Tools/Equipment	300,000
Insurance	33,000
Office Supplies and Production Travel	100,000
Repairs and Maintenance	300,000
Utilities	180,000
Telephone and Telegraph	35,000
Indirect Labor	311,000
Shop Supplies	170,000
Business Fees and Transportation Permits	21,000
Quality Assurance	161,000
Warranty Service @ 1% of Sales	500,000
Shift Premium @ 7% of Hourly Payroll	438,000
On-Line Computer Assistance	200,000
Total Production Overhead	$4,350,500
Production Overhead/Revenue	7.9%

SANVAWT, INC. (Scenario #1d)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(192 Units/Year)

VAWT Description:		
Peak Electrical Capacity	120 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	28.5 kW	
Annual Energy Output @ 15 mph site	250,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 8,110	
Rotor Tower	4,150	
Tiedowns	2,300	
Transmission and Drive Train	15,800	
Electricals	6,000	
Miscellaneous	540	
Direct Cost		$36,900
Production Overhead @ 7.9%		$ 3,950
Corporate Overhead @ 7.9%		3,950
Profit @ 10.4%		5,200
Selling Price (F.O.B. Plant):		$50,000
Typical Delivery Cost		$ 500
Typical On-Site Costs		30,000
Estimated Installed Cost to Owner		$80,500

SANVAWT, INC. (Scenario #1d)
ON-SITE WORK
120 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 16,000
(2) Fencing, Environmental Covers and Subsystem Erection	14,000
Total On-Site Costs	$ 30,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 mi.	$500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1d)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(149 Units/Year)

VAWT Description:

Peak Electrical Capacity	220 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	56.3 kW
Annual Energy Output @ 15 mph site	493,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$14,000	
Rotor Tower	11,570	
Tiedowns	5,500	
Transmission and Drive Train	24,500	
Electricals	9,500	
Miscellaneous	1,350	
Direct Cost		$ 66,420
Production Overhead @ 7.9%		$ 7,110
Corporate Overhead @ 7.9%		7,110
Profit @ 10.4%		9,360
Selling Price (F.O.B. Plant):		$ 90,000
Typical Delivery Cost		$ 1,500
Typical On-Site Costs		45,000
Estimated Installed Cost to Owner		$136,500

SANVAWT, INC. (Scenario #1d)
ON-SITE WORK
200 kW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$24,500
(2) Fencing, Environmental Covers and Subsystem Erection	20,500
Total On-Site Costs	$45,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 mi.	$1,500

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC. (Scenario #1d)
Cost Estimate and Selling Price
500 kW Vertical Axis Wind Turbine

(63 Units/Year)

VAWT Description:		
Peak Electrical Capacity	480 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	122.1 kW	
Annual Energy Output @ 15 mph site	1,070,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 23,300	
Rotor Tower	29,880	
Tiedowns	14,000	
Transmission and Drive Train	54,500	
Electricals	30,500	
Miscellaneous	2,800	
Direct Cost		$154,980
Production Overhead @ 7.9%		$ 16,590
Corporate Overhead @ 7.9%		16,590
Profit @ 10.4%		21,840
Selling Price (F.O.B. Plant):		$210,000
Typical Delivery Cost		$ 3,000
Typical On-Site Costs		82,000
Estimated Installed Cost to Owner		$295,000

SANVAWT, INC. (Scenario #1d)
ON-SITE WORK
1.6 MW Vertical Axis Wind Turbine

For purposes of these estimates, the site is assumed to be owned by an electricity generating utility, and site improvements and VAWT erection will be performed by an independent construction contractor paying average union field construction wages.

Site Improvement and VAWT Erection Costs:

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$133,000
(2) Fencing, Environmental Covers and Subsystem Erection	67,000
Total On-Site Costs	$200,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
1.6 MW	235,830#	12 @ 250 mi.	$8,000

State and Local Sales and Use Taxes:

Not Applicable (Too Site Specific for Generalization)

SANVAWT, INC.
Business Scenario #2

Business Objective: Profitably serve the region's electricity users with small-to-medium (up to 400 kW) Vertical Axis Wind Turbines which would be interfaced with the utility grid's distribution lines to operate in an electrical energy conservation mode.

Factory Functions:

Purchase materials needed for in-plant fabrication and fabricate specific components.

Purchase some fabricated components for in-plant assembly or collection for coordinated delivery.

Assemble fabricated and purchased components into manageable subassemblies and subsystems.

Implement quality control program to assure adequacy and fit of all subsystems.

Package, store and load all subassemblies and individual components for shipment.

Marketing Functions:

Define and price line of standard VAWTs offered for sale.

Prepare necessary advertising and promotion programs to interest potential customers in SANVAWT machines.

Establish distribution system adequate to reach and serve many small purchasers.

Train and support distributors and/or dealers with necessary sales aids and engineering assistance to make them effective in securing orders and servicing customers.

Administer execution of the terms and conditions of multiple sales when orders are received.

Arrange logistics of production, delivery, staging and erection of the VAWTs in conjunction with the distributor, the customer and/or the distributor's or customer's erection contractor.

Reward the distributors financially for securing orders and servicing customers.

Delivery Functions:

Deliver the VAWT subsystems, without damage or loss, to the appropriate site, perhaps with an interim stop at a distributor's warehouse, by means of truck.

On-Site Functions:

Prepare the site for assembly and erection of the VAWT by building necessary base foundations and tie-down footings.

Unload and account for all delivered subsystems and components and, where possible, install them sequentially into position on the foundation.

Complete the assembly and erection of all components and subsystems and make necessary interface connections in conjunction with the electric utility, to the utility's distribution line and to the user's load.

Start up the VAWTs to assure successful operation and make necessary corrections and modifications.

Train the customer in procedures for operating and maintaining the VAWTs and turn over operating, service and warranty data.

Monitor, through the distributor, operations and provide appropriate service during the warranty period.

Product Line Summary:

VAWT Designation	Height/Diameter (Feet)	Wind Regime (mph)	Rated Power (kW)	Annual Energy (kWh)
2718-5	27 x 18	12	5	8,480
2718-9	27 x 18	15	9	16,400
2718-16	27 x 18	18	16	30,100
4530-18	45 x 30	12	18	30,200
4530-30	45 x 30	15	30	60,000
4530-50	45 x 30	18	50	104,800
8355-80	83 x 55	12	80	136,000
8355-120	83 x 55	15	120	250,000
8355-210	83 x 55	18	210	480,000
11375-135	113 x 75	12	135	265,000
11375-220	113 x 75	15	220	493,000
11375-390	113 x 75	18	390	890,000

Facility and People Requirements:

	Scenario			
	#1a	#1b	#1c	#1d
Production Space (S.F.)	30,000	30,000	70,000	110,000
Office Space (S.F.)	4,500	4,500	9,500	16,500
Personnel (No. People)	68	129	329	659
Management/Clerical	15	25	44	75
Marketing/Sales	2	2	3	6
Indirect Labor	5	9	22	39
Direct Labor	46	93	260	539

SANVAWT, INC. (Business Scenario #2a)

Mission:	Fabricate, sell and service standard Vertical Axis Wind Turbines for non-utility electricity users within 500 miles of the SANVAWT plant.
Product Line:	10 kW, 30 kW, 120 kW and 200 kW VAWTs with appropriate accessories.
Basic Company:	A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.
Sales Goals:	A product mix of the four sizes of turbines that will result in delivery of 8 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs is assumed, as is the production capability of the plant. The annual revenues are projected, in 1978 dollars, as $5.5 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Direct Labor and Material Costs	$ 7,001	$11,082	$40,984	$ 74,370
Production Overhead	1,306	2,067	7,644	13,871
Corporate Overhead	1,235	1,956	7,232	13,124
Profit	1,168	1,845	6,840	12,385
Selling Price (F.O.B. Plant):	$10,710	$16,950	$62,700	$113,750
Distributor Costs/Profit @ 20%	$ 2,142	$ 3,390	$12,540	$ 22,750
State/Local Sales or Use Tax	428	678	2,508	4,550
Estimated Delivery (250 mi. average):	250	250	250	750
Delivered Cost:	$13,530	$21,268	$77,998	$141,800
On-Site Costs:	$ 3,000	$ 4,200	$20,000	$ 31,000
Installed Costs:	$16,530	$25,468	$97,998	$172,800

SANVAWT, INC. (Business Scenario # 2a)

Costs to the User:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 MW
Installed Cost ($):	16,530	25,468	97,998	172,800
Ownership Cost ($):				
Annualized @				
12%	1,980	3,060	11,760	20,760
15%	2,475	3,825	14,700	25,950
18%	2,970	4,590	17,640	31,140
Annual Energy:				
kWh @				
12 mph mean	8,480	30,200	136,000	265,000
15 mph mean	16,400	60,000	250,000	493,000
18 mph mean	30,100	104,800	480,000	890,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.233	.101	.086	.078
15 mph	.121	.051	.047	.042
18 mph	.066	.029	.024	.023
15% Annualized				
12 mph	.292	.127	.108	.098
15 mph	.151	.064	.059	.053
18 mph	.082	.036	.031	.292
18% Annualized				
12 mph	.350	.152	.130	.118
15 mph	.181	.076	.070	.063
18 mph	.099	.044	.037	.350

SANVAWT, INC. (Scenario #2a)
Corporate Financial Plan
8 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$5,330
Cost of Goods Sold:		
Direct Labor and Material	$3,485	
Production Overhead	650	
Total		$4,135
Corporate Overhead:		
Interest on Borrowed Capital	$ 160	
Sales and Administrative Expense	455	
Total		$ 615
Profit (Loss) Before Federal Taxes		$ 580
Capital in Use:		
Accounts Receivable - 40 Days	$ 550	
Inventory	500	
Fixed Capital	400	
Total	$1,450	
Return on Capital in Use	40.0%	

8 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
10 kW	180	1,620 kW
30 kW	85	2,550 kW
120 kW	20	2,400 kW
200 kW	8	1,760 kW
Totals	293	8,330 kW

SANVAWT, INC. (Scenario #2a)
8 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - Six People	$149,000
Other Payroll Costs @ 30%	44,700
Office Rent - 2,500 Square Feet	12,500
Telephone and Telegraph	30,000
Office Supplies and Postage	10,000
Printing and Photocopy	6,000
Travel and Per Diem Expense	25,000
Entertainment	8,000
Public Relations and Advertising	50,000
Legal Expense	20,000
Technology Development	50,000
Employee Relocation Allowance	20,000
Uncollectable Accounts - .5% of Sales	25,000
State and Local Corporate Taxes	6,000
Interest	160,000
Total Corporate Overhead	$616,200
Corporate Overhead/Revenue	11.5%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 11 People (Mgt. and Clerical)	$199,000
Other Payroll Costs @ 30%	60,000
Plant Rental - 32,000 Square Feet	50,000
Depreciation and Rental of Tools/Equipment	100,000
Insurance	7,500
Office Supplies and Production Travel	18,000
Repairs and Maintenance	50,000
Utilities	28,000
Telephone and Telegraph	8,000
Indirect Labor	38,000
Shop Supplies	24,000
Business Fees and Transportation Permits	2,500
Quality Assurance	15,000
Warranty Service @ 1% of Sales	50,000
Total Production Overhead	$650,000
Production Overhead/Revenue	12.2%

SANVAWT, INC. (Scenario #2a)
Cost Estimate and Selling Price
10 kW Vertical Axis Wind Turbine

(180 Units/Year)

VAWT Description:	
Peak Electrical Capacity	9 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	1.9 kW
Annual Energy Output @ 15 mph Site	16,400 kWh

Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 660	
Rotor Tower	1,950	
Tiedowns	550	
Transmission and Drive Train	2,400	
Electricals	1,315	
Miscellaneous	126	
Direct Cost		$ 7,001
Production Overhead @ 12.2%		$ 1,306
Corporate Overhead @ 11.5%		1,235
Profit @ 10.9%		1,168
Selling Price (F.O.B. Plant):		$10,710
Typical State/Local Sales or Use Tax		$ 428
Typical Distributor Cost/Profit @ 20%		2,142
Typical Delivery Cost		250
Typical On-Site Costs		3,000
Estimated Installed Cost to Owner		$16,530

SANVAWT, INC. (Scenario #2a)
DISTRIBUTION AND ON-SITE WORK
10 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 10 kW = $428.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$1,400
(2) Subsystem Erection	1,600
Total On-Site Costs	$3,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
10 kW	3,820#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2a)
Cost Estimate and Selling Price
30 kW Vertical Axis Wind Turbine

(85 Units/Year)

VAWT Description:

Peak Electrical Capacity	30 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	6.8 kW
Annual Energy Output @ 15 mph Site	60,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$ 1,695	
Rotor Tower	2,635	
Tiedowns	1,190	
Transmission and Drive Train	3,810	
Electricals	1,520	
Miscellaneous	232	
Direct Cost		$11,082
Production Overhead @ 12.2%		$ 2,067
Corporate Overhead @ 11.5%		1,956
Profit @ 10.9%		1,845
Selling Price (F.O.B. Plant):		$16,950
Typical State/Local Sales or Use Tax		$ 678
Typical Distributor Cost/Profit @ 20%		3,390
Typical Delivery Cost		250
Typical On-Site Costs		4,200
Estimated Installed Cost to Owner		$25,468

SANVAWT, INC. (Scenario #2a)
DISTRIBUTION AND ON-SITE WORK
30 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 30 kW = $678.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$2,500
(2) Subsystem Erection	1,700
Total On-Site Costs	$4,200

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
30 kW	8,420#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2a)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(20 Units/Year)

VAWT Description:

Peak Electrical Capacity	120 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	28.5 kW
Annual Energy Output @ 15 mph Site	250,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$ 9,800	
Rotor Tower	5,000	
Tiedowns	2,500	
Transmission and Drive Train	16,500	
Electricals	6,500	
Miscellaneous	684	
Direct Cost		$40,984
Production Overhead @ 12.2%		$ 7,644
Corporate Overhead @ 11.5%		7,232
Profit @ 10.9%		6,840
Selling Price (F.O.B. Plant):		$62,700
Typical State/Local Sales or Use Tax		$ 2,508
Typical Distributor Cost /Profit @ 20%		12,540
Typical Delivery Cost		250
Typical On-Site Costs		20,000
Estimated Installed Cost to Owner		$97,998

SANVAWT, INC. (Scenario #2a)
DISTRIBUTION AND ON-SITE WORK
120 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 120 kW = $2,508.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 9,000
(2) Subsystem Erection	11,000
Total On-Site Costs	$20,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario # 2a)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(8 Units/Year)

VAWT Description:	
Peak Electrical Capacity	220 kW
Wind Velocity @ Peak Capacity	31 mph
Average Electrical Output @ 15 mph	56.3 kW
Annual Energy Output @ 15 mph Site	493,000 kWh

Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$15,500	
Rotor Tower	12,500	
Tiedowns	6,100	
Transmission and Drive Train	26,000	
Electricals	13,000	
Miscellaneous	1,270	
Direct Cost		$ 74,370
Production Overhead @ 12.2%		$ 13,871
Corporate Overhead @ 11.5%		13,124
Profit @ 10.9%		12,385
Selling Price (F.O.B. Plant):		$113,750
Typical State/Local Sales or Use Tax		$ 4,550
Typical Distributor Cost/ Profit @ 20%		22,750
Typical Delivery Cost		750
Typical On-Site Costs		31,000
Estimated Installed Cost to Owner		$172,800

SANVAWT, INC. (Scenario #2a)
DISTRIBUTION AND ON-SITE WORK
200 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 200 kW = $4,550.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$15,000
(2) Subsystem Erection	16,000
Total On-Site Costs	$31,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 miles	$750

SANVAWT, INC. (Business Scenario #2b)

Mission: Fabricate, sell and service standard Vertical Axis Wind Turbines for non-utility electricity users within 500 miles of the SANVAWT plant.

Product Line: 10 kW, 30 kW, 120 kW and 200 kW VAWTs with appropriate accessories.

Basic Company: A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.

Sales Goals: A product mix of the four sizes of turbines that will result in delivery of 18 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs is assumed, as is the production capability of the plant. The annual revenues are projected, in 1978 dollars, as $10 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Direct Labor and Material Costs	$ 6,600	$10,500	$38,000	$ 70,000
Production Overhead	1,035	1,646	5,958	10,975
Corporate Overhead	755	1,201	4,347	8,008
Profit	932	1,483	5,367	9,887
Selling Price (F.O.B. Plant):	$ 9,322	$14,830	$53,672	$ 98,870
Distributor Costs/Profit @ 15%	$ 1,398	$ 2,225	$ 8,051	$ 14,830
State/Local Sales or Use Tax	373	593	2,147	3,955
Estimated Delivery (250 mi. average):	250	250	250	750
Delivered Cost:	$11,343	$17,898	$61,973	$118,405
On-Site Costs:	$ 3,000	$ 4,200	$20,000	$ 31,000
Installed Costs:	$14,343	$22,098	$81,973	$149,405

SANVAWT, INC. (Business Scenario #2b)

Costs to the User:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Installed Cost ($):	14,343	22,098	81,973	149,405
Ownership Cost ($):				
Annualized @				
12%	1,721	2,652	9,837	17,929
15%	2,151	3,315	12,296	22,411
18%	2,582	3,978	14,755	26,893
Annual Energy:				
kWh @				
12 mph mean	8,480	30,200	136,000	265,000
15 mph mean	16,400	60,000	250,000	493,000
18 mph mean	30,100	104,800	480,000	890,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.203	.088	.072	.068
15 mph	.105	.044	.039	.036
18 mph	.057	.025	.020	.020
15% Annualized				
12 mph	.254	.110	.090	.085
15 mph	.131	.055	.049	.045
18 mph	.071	.032	.026	.025
18% Annualized				
12 mph	.304	.132	.108	.101
15 mph	.157	.066	.059	.055
18 mph	.086	.038	.031	.030

SANVAWT, INC. (Scenario # 2b)
Corporate Financial Plan
18 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$10,000
Cost of Goods Sold:		
Direct Labor and Material	$7,078	
Production Overhead	1,111	
Total		$ 8,189
Corporate Overhead:		
Interest on Borrowed Capital	$ 250	
Sales and Administrative Expense	561	
Total		$ 811
Profit (Loss) Before Federal Taxes		$ 1,000
Capital in Use:		
Accounts Receivable - 36.5 Days	$1,000	
Inventory	800	
Fixed Capital	700	
Total	$2,500	
Return on Capital in Use	40%	

18 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
10 kW	322	2,898 kW
30 kW	180	5,400 kW
120 kW	40	4,800 kW
200 kW	22	4,840 kW
Totals	564	17,938 kW

SANVAWT, INC. (Scenario #2b)
18 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - Eight People	$169,000
Other Payroll Costs @ 30%	50,700
Office Rent - 2,500 Square Feet	12,500
Telephone and Telegraph	35,000
Office Supplies and Postage	12,000
Printing and Photocopy	8,000
Travel and Per Diem Expense	30,000
Entertainment	10,000
Public Relations and Advertising	60,000
Legal Expense	25,000
Technology Development	57,500
Employee Relocation Allowance	30,000
Uncollectable Accounts — .5% of Sales	50,000
State and Local Corporate Taxes	12,000
Interest	250,000
Total Corporate Overhead	$811,200
Corporate Overhead/Revenue	8.1%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 19 People (Mgt. and Clerical)	$ 332,000
Other Payroll Costs @ 30%	99,600
Plant Rental - 32,000 Square Feet	50,000
Depreciation and Rental of Tools/Equipment	140,000
Insurance	12,000
Office Supplies and Production Travel	18,000
Repairs and Maintenance	75,000
Utilities	45,000
Telephone and Telegraph	11,000
Indirect Labor	73,000
Shop Supplies	40,000
Business Fees and Transportation Permits	5,000
Quality Assurance	30,000
Warranty Service @ 1% of Sales	100,000
Shift Premium @ 7% of Hourly Payroll	70,000
Total Production Overhead	$1,110,600
Production Overhead/Revenue	11.1%

SANVAWT, INC. (Scenario #2b)
Cost Estimate and Selling Price
10 kW Vertical Axis Wind Turbine

(322 Units/Year)

VAWT Description:

Peak Electrical Capacity	9 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	1.9 kW
Annual Energy Output @ 15 mph Site	16,400 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$ 600	
Rotor Tower	1,750	
Tiedowns	520	
Transmission and Drive Train	2,300	
Electricals	1,310	
Miscellaneous	120	
Direct Cost		$ 6,600
Production Overhead @ 11.1%		$ 1,035
Corporate Overhead @ 8.1%		755
Profit @ 10%		932
Selling Price (F.O.B. Plant):		$ 9,322
Typical State/Local Sales or Use Tax		$ 373
Typical Distributor Cost/Profit @ 15%		1,398
Typical Delivery Cost		250
Typical On-Site Costs		3,000
Estimated Installed Cost to Owner		$14,343

SANVAWT, INC. (Scenario #2b)
DISTRIBUTION AND ON-SITE WORK
10 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 10 kW = $373.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$1,400
(2) Subsystem Erection	1,600
Total On-Site Costs	$3,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
10 kW	3,820#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2b)
Cost Estimate and Selling Price
30 kW Vertical Axis Wind Turbine

(180 Units/Year)

VAWT Description:

Peak Electrical Capacity	30 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	6.8 kW
Annual Energy Output @ 15 mph Site	60,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$1,560	
Rotor Tower	2,400	
Tiedowns	1,150	
Transmission and Drive Train	3,660	
Electricals	1,500	
Miscellaneous	230	
Direct Cost		$10,500
Production Overhead @ 11.1%		$ 1,646
Corporate Overhead @ 8.1%		1,201
Profit @ 10%		1,483
Selling Price (F.O.B. Plant):		$14,830
Typical State/Local Sales or Use Tax		$ 593
Typical Distributor Cost/Profit @ 15%		2,225
Typical Delivery Cost		250
Typical On-Site Costs		4,200
Estimated Installed Cost to Owner		$22,098

SANVAWT, INC. (Scenario #2b)
DISTRIBUTION AND ON-SITE WORK
30 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 30 kW = $593.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$2,500
(2) Subsystem Erection	1,700
Total On-Site Costs	$4,200

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
30 kW	8,420#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2b)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(40 Units/Year)

VAWT Description:		
Peak Electrical Capacity	120 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	28.5 kW	
Annual Energy Output @ 15 mph Site	250,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 8,450	
Rotor Tower	4,200	
Tiedowns	2,400	
Transmission and Drive Train	16,300	
Electricals	6,200	
Miscellaneous	450	
Direct Cost		$38,000
Production Overhead @ 11.1%		$ 5,958
Corporate Overhead @ 8.1%		4,347
Profit @ 10%		5,367
Selling Price (F.O.B. Plant):		$53,672
Typical State/Local Sales or Use Tax		$ 2,147
Typical Distributor Cost/Profit @ 15%		8,051
Typical Delivery Cost		250
Typical On-Site Costs		20,000
Estimated Installed Cost to Owner		$81,973

SANVAWT, INC. (Scenario #2b)
DISTRIBUTION AND ON-SITE WORK
120 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 120 kW = $2,147.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 9,000
(2) Subsystem Erection	11,000
Total On-Site Costs	$20,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario # 2b)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(22 Units/Year)

VAWT Description:		
Peak Electrical Capacity	220 kW	
Wind Velocity @ Peak Capacity	31 mph	
Average Electrical Output @ 15 mph	56.3 kW	
Annual Energy Output @ 15 mph Site	493,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$14,800	
Rotor Tower	11,700	
Tiedowns	5,800	
Transmission and Drive Train	25,500	
Electricals	11,000	
Miscellaneous	1,200	
Direct Cost		$ 70,000
Production Overhead @ 11.1%		$ 10,975
Corporate Overhead @ 8.1%		8,008
Profit @ 10%		9,887
Selling Price (F.O.B. Plant):		$ 98,870
Typical State/Local Sales or Use Tax		$ 3,955
Typical Distributor Cost/Profit @ 15%		14,830
Typical Delivery Cost		750
Typical On-Site Costs		31,000
Estimated Installed Cost to Owner		$149,405

SANVAWT, INC. (Scenario #2b)
DISTRIBUTION AND ON-SITE WORK
200 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 200 kW = $3,955.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$15,000
(2) Subsystem Erection	16,000
Total On-Site Costs	$31,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 miles	$750

SANVAWT, INC. (Business Scenario #2c)

Mission:	Fabricate, sell and service standard Vertical Axis Wind Turbines for non-utility electricity users within 500 miles of the SANVAWT plant.
Product Line:	10 kW, 30 kW, 120 kW and 200 kW VAWTs with appropriate accessories.
Basic Company:	A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.
Sales Goals:	A product mix of the four sizes of turbines that will result in delivery of 49 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs is assumed, as is the production capability of the plant. The annual revenues are projected, in 1978 dollars, as $25 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Direct Labor and Material Costs	$ 6,395	$10,096	$37,428	$ 67,958
Production Overhead	812	1,282	4,752	8,628
Corporate Overhead	494	780	2,890	5,248
Profit	670	1,057	3,919	7,116
Selling Price (F.O.B. Plant):	$ 8,370	$13,215	$48,990	$ 88,950
Distributor Costs/Profit @ 10%	$ 837	$ 1,322	$ 4,899	$ 8,895
State/Local Sales or Use Tax	335	529	1,960	3,558
Estimated Delivery (250 mile average):	250	250	250	750
Delivered Cost:	$ 9,792	$15,316	$56,099	$102,153
On-Site Costs:	$ 2,800	$ 4,000	$20,000	$ 31,000
Installed Costs:	$12,592	$19,316	$76,099	$133,153

SANVAWT, INC. (Business Scenario #2c)

Costs to the User:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Installed Cost ($):	12,592	19,316	76,099	133,153
Ownership Cost ($):				
Annualized @				
12%	1,511	2,318	9,132	15,978
15%	1,889	2,897	11,415	19,973
18%	2,267	3,477	13,698	23,968
Annual Energy:				
kWh @				
12 mph mean	8,480	30,200	136,000	265,000
15 mph mean	16,400	60,000	250,000	493,000
18 mph mean	30,100	104,800	480,000	890,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.178	.077	.067	.060
15 mph	.092	.039	.037	.032
18 mph	.050	.022	.019	.017
15% Annualized				
12 mph	.223	.096	.084	.075
15 mph	.115	.048	.046	.040
18 mph	.063	.028	.024	.022
18% Annualized				
12 mph	.267	.115	.101	.090
15 mph	.138	.058	.055	.049
18 mph	.075	.033	.029	.027

SANVAWT, INC. (Scenario #2c)
Corporate Financial Plan
49 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$25,000
Cost of Goods Sold:		
Direct Labor and Material	$19,094	
Production Overhead	2,425	
Total		$21,519
Corporate Overhead:		
Interest on Borrowed Capital	$ 500	
Sales and Administrative Expense	981	
Total		$ 1,481
Profit (Loss) Before Federal Taxes		$ 2,000
Capital in Use:		
Accounts Receivable - 365 Days	$ 2,500	
Inventory	1,500	
Fixed Capital	1,000	
Total	$ 5,000	
Return on Capital in Use	40%	

49 MW PRODUCTION PLAN

VAWT Size Rated Power	Number of Machines	Installed Electricity Capacity
10 kW	1,080	10,800 kW
30 kW	500	15,000 kW
120 kW	100	12,000 kW
200 kW	50	11,000 kW
Totals	1,730	48,800 kW

SANVAWT, INC. (Scenario #2c)
49 MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - 12 People	$ 220,000
Other Payroll Costs @ 30%	66,000
Office Rent - 5,000 Square Feet	25,000
Telephone and Telegraph	50,000
Office Supplies and Postage	25,000
Printing and Photocopy	15,000
Travel and Per Diem Expense	50,000
Entertainment	10,000
Public Relations and Advertising	125,000
Legal Expense	50,000
Technology Development	150,000
Employee Relocation Allowance	50,000
Uncollectable Accounts — .5% of Sales	125,000
State and Local Corporate Taxes	20,000
Interest	500,000
Total Corporate Overhead	$1,481,000
Corporate Overhead/Revenue	5.9%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 35 People (Mgt. and Clerical)	$ 623,500
Other Payroll Costs @ 30%	186,750
Plant Rental - 74,500 Square Feet	117,000
Depreciation and Rental of Tools/Equipment	200,000
Insurance	21,000
Office Supplies and Production Travel	58,000
Repairs and Maintenance	160,000
Utilities	90,000
Telephone and Telegraph	20,000
Indirect Labor	175,000
Shop Supplies	90,000
Business Fees and Transportation Permits	12,000
Quality Assurance	88,000
Warranty Service @ 1% of Sales	250,000
Shift Premium @ 7% of Hourly Payroll	214,000
On-Line Computer Assistance	120,000
Total Production Overhead	$2,425,250
Production Overhead/Revenue	9.7%

SANVAWT, INC. (Scenario #2c)
Cost Estimate and Selling Price
10 kW Vertical Axis Wind Turbine

(1,080 Units/Year)

VAWT Description:		
Peak Electrical Capacity	9 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	1.9 kW	
Annual Energy Output @ 15 mph Site	16,400 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 580	
Rotor Tower	1,690	
Tiedowns	500	
Transmission and Drive Train	2,250	
Electricals	1,255	
Miscellaneous	120	
Direct Cost		$ 6,395
Production Overhead @ 9.7%		$ 812
Corporate Overhead @ 5.9%		494
Profit @ 8.0%		670
Selling Price (F.O.B. Plant):		$ 8,370
Typical State/Local Sales or Use Tax		$ 335
Typical Distributor Cost /Profit @ 10%		837
Typical Delivery Cost		250
Typical On-Site Costs		2,800
Estimated Installed Cost to Owner		$12,592

SANVAWT, INC. (Scenario #2c)
DISTRIBUTION AND ON-SITE WORK
10 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 10 kW = $335.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$1,300
(2) Subsystem Erection	1,500
Total On-Site Costs	$2,800

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
10 kW	3,820#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2c)
Cost Estimate and Selling Price
30 kW Vertical Axis Wind Turbine

(500 Units/Year)

VAWT Description:		
Peak Electrical Capacity	30 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	6.8 kW	
Annual Energy Output @ 15 mph Site	60,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 1,526	
Rotor Tower	2,350	
Tiedowns	1,100	
Transmission and Drive Train	3,520	
Electricals	1,400	
Miscellaneous	200	
Direct Cost		$10,096
Production Overhead @ 9.7%		$ 1,282
Corporate Overhead @ 5.9%		780
Profit @ 8.0%		1,057
Selling Price (F.O.B. Plant):		$13,215
Typical State/Local Sales or Use Tax		$ 528
Typical Distributor Cost/Profit @ 10%		1,322
Typical Delivery Cost		250
Typical On-Site Costs		4,000
Estimated Installed Cost to Owner		$19,316

SANVAWT, INC. (Scenario #2c)
DISTRIBUTION AND ON-SITE WORK
30 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 30 kW - $529.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$2,400
(2) Subsystem Erection	1,600
Total On-Site Costs	$4,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
30 kW	8,420#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2c)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(100 Units/Year)

VAWT Description:		
Peak Electrical Capacity	120 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	28.5 kW	
Annual Energy Output @ 15 mph Site	250,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 8,150	
Rotor Tower	4,150	
Tiedowns	2,400	
Transmission and Drive Train	16,200	
Electricals	6,100	
Miscellaneous	428	
Direct Cost		$37,428
Production Overhead @ 9.7%		$ 4,752
Corporate Overhead @ 5.9%		2,890
Profit @ 8.0%		3,919
Selling Price (F.O.B. Plant):		$48,990
Typical State/Local Sales or Use Tax		$ 1,960
Typical Distributor Cost/Profit @ 10%		4,899
Typical Delivery Cost		250
Typical On-Site Costs		20,000
Estimated Installed Cost to Owner		$76,099

SANVAWT, INC. (Scenario #2c)
DISTRIBUTION AND ON-SITE WORK
120 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 120 kW = $1,960.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 9,000
(2) Subsystem Erection	11,000
Total On-Site Costs	$20,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2c)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(50 Units/Year)

VAWT Description:

Peak Electrical Capacity	220 kW
Wind Velocity @ Peak Capacity	31 mph
Average Electrical Output @ 15 mph	56.3 kW
Annual Energy Output @ 15 mph Site	493,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$14,400	
Rotor Tower	11,700	
Tiedowns	5,500	
Transmission and Drive Train	25,500	
Electricals	9,500	
Miscellaneous	1,358	
Direct Cost		$ 67,958
Production Overhead @ 9.7%		$ 8,628
Corporate Overhead @ 5.9%		5,248
Profit @ 8.0%		7,116
Selling Price (F.O.B. Plant):		$ 88,950
Typical State/Local Sales or Use Tax		$ 3,558
Typical Distributor Cost/Profit @ 10%		8,895
Typical Delivery Cost		750
Typical On-Site Costs		31,000
Estimated Installed Cost to Owner		$133,153

SANVAWT, INC. (Scenario #2c)
DISTRIBUTION AND ON-SITE WORK
200 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 200 kW = $3,558.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$15,000
(2) Subsystem Erection	16,000
Total On-Site Costs	$31,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 miles	$750

SANVAWT, INC. (Business Scenario #2d)

Mission: Fabricate, sell and service standard vertical Axis Wind Turbines for non-utility electricity users within 500 miles of the SANVAWT plant.

Product Line: 10 kW, 30 kW, 120 kW and 200 kW VAWTs with appropriate accessories.

Basic Company: A single plant facility with all personnel, except field salespeople, housed in that building. The company is assumed to be a "Greenfield" Corporation optimized for production and sale of VAWTs.

Sales Goals: A product mix of the four sizes of turbines that will result in delivery of 104 megawatts of installed electricity generating peak capacity per year. Established markets for that quantity of VAWTs is assumed, as is the production capability of the plant. The annual revenues are projected, in 1978 dollars, as $50 million.

Prices and Installed Costs of Standard VAWTs:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Direct Labor and Material Costs	$ 6,000	$ 9,600	$36,000	$ 65,000
Production Overhead	594	950	3,564	6,435
Corporate Overhead	383	614	2,301	4,154
Profit	541	866	3,248	5,865
Selling Price (F.O.B. Plant):	$ 7,519	$12,030	$45,113	$ 81,454
Distributor Costs/Profit @ 6%	$ 451	$ 722	$ 2,707	$ 4,887
State/Local Sales or Use Tax	301	481	1,805	3,258
Estimated Delivery (250 mile average):	250	250	250	750
Delivered Cost:	$ 8,521	$13,483	$49,874	$ 90,349
On-Site Costs:	$ 2,000	$ 3,500	$18,000	$ 28,000
Installed Costs:	$10,521	$16,983	$67,874	$118,349

SANVAWT, INC. (Business Scenario #2d)

Costs to the User:

	VAWT Capacity			
	10 kW	30 kW	120 kW	200 kW
Installed Cost ($):	10,521	16,983	67,874	118,349
Ownership Cost ($):				
Annualized @				
12%	1,263	2,038	8,145	14,202
15%	1,578	2,547	10,181	17,752
18%	1,894	3,057	12,217	21,303
Annual Energy:				
kWh @				
12 mph mean	8,480	30,200	136,000	265,000
15 mph mean	16,400	60,000	250,000	493,000
18 mph mean	30,100	104,800	480,000	890,000
Energy Cost ($/kWh):				
12% Annualized				
12 mph	.149	.067	.060	.054
15 mph	.077	.034	.033	.029
18 mph	.042	.019	.017	.016
15% Annualized				
12 mph	.186	.084	.075	.067
15 mph	.096	.042	.041	.036
18 mph	.052	.024	.021	.020
18% Annualized				
12 mph	.223	.101	.090	.080
15 mph	.115	.051	.049	.043
18 mph	.063	.029	.025	.024

SANVAWT, INC. (Scenario #2d)
Corporate Financial Plan
104 MW Annual Production Volume

(All Numbers in Thousands)

Sales Revenue		$50,000
Cost of Goods Sold:		
Direct Labor and Material	$39,880	
Production Overhead	3,950	
Total		$43,830
Corporate Overhead:		
Interest on Borrowed Capital	$ 900	
Sales and Administrative Expense	1,670	
Total		$ 2,570
Profit (Loss) Before Federal Taxes		$ 3,600
Capital in Use:		
Accounts Receivable - 33 Days	$ 4,500	
Inventory	3,000	
Fixed Capital	1,500	
Total	$ 9,000	
Return on Capital in Use	40%	

104 MW PRODUCTION PLAN

VAWT Size Rated Power		Number of Machines	Installed Electricity Capacity
10 kW		2,140	19,260 kW
30 kW		1,000	30,000 kW
120 kW		250	26,400 kW
200 kW		130	28,600 kW
	Totals	3,520	104,260 kW

SANVAWT, INC. (Scenario #2d)
104MW Annual Production Volume

Corporate Overhead Budget

Item of Expense	Sales and Administrative Budget
Salaries - 19 People	$ 407,500
Other Payroll Costs @ 30%	122,250
Office Rent - 5,000 Square Feet	25,000
Telephone and Telegraph	90,000
Office Supplies and Postage	45,000
Printing and Photocopy	25,000
Travel and Per Diem Expense	100,000
Entertainment	20,000
Public Relations and Advertising	200,000
Legal Expense	75,000
Technology Development	200,000
Employee Relocation Allowance	75,000
Uncollectable Accounts — .5% of Sales	250,000
State and Local Corporate Taxes	35,000
Interest	900,000
Total Corporate Overhead	$2,569,750
Corporate Overhead/Revenue	5.1%

Production Overhead Budget

Item of Expense	Budget
Salaries and Wages - 62 People (Mgt. and Clerical)	$1,086,500
Other Payroll Costs @ 30%	326,000
Plant Rental - 118,000 Square Feet	189,000
Depreciation and Rental of Tools/Equipment	300,000
Insurance	33,000
Office Supplies and Production Travel	100,000
Repairs and Maintenance	300,000
Utilities	180,000
Telephone and Telegraph	35,000
Indirect Labor	311,000
Shop Supplies	170,000
Business Fees and Transportation Permits	21,000
Quality Assurance	161,000
Warranty Service @ 1% of Sales	500,000
Shift Premium @ 7% of Hourly Payroll	438,000
On-line Computer Assistance	200,000
Total Production Overhead	$4,350,500
Production Overhead/Revenue	7.9%

SANVAWT, INC. (Scenario #2d)
Cost Estimate and Selling Price
10 kW Vertical Axis Wind Turbine

(2,140 Units/Year)

VAWT Description:		
Peak Electrical Capacity		9 kW
Wind Velocity @ Peak Capacity		30 mph
Average Electrical Output @ 15 mph		1.9 kW
Annual Energy Output @ 15 mph Site		16,400 kWh
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$ 580	
Rotor Tower	1,485	
Tiedowns	500	
Transmission and Drive Train	2,160	
Electricals	1,165	
Miscellaneous	110	
Direct Cost		$ 6,000
Production Overhead @ 7.9%		$ 594
Corporate Overhead @ 5.1%		383
Profit @ 7.2%		541
Selling Price (F.O.B. Plant):		$ 7,519
Typical State/Local Sales or Use Tax		$ 301
Typical Distributor Cost/Profit @ 6%		451
Typical Delivery Cost		250
Typical On-Site Costs		2,000
Estimated Installed Cost to Owner		$10,521

SANVAWT, INC. (Scenario #2d)
DISTRIBUTION AND ON-SITE WORK
10 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 10 kW = $327.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 900
(2) Subsystem Erection	1,100
Total On-Site Costs	$2,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
10 kW	3,820#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2d)
Cost Estimate and Selling Price
30 kW Vertical Axis Wind Turbine

(1,000 Units/Year)

VAWT Description:		
Peak Electrical Capacity	30 kW	
Wind Velocity @ Peak Capacity	30 mph	
Average Electrical Output @ 15 mph	6.8 kW	
Annual Energy Output @ 15 mph Site	60,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$1,500	
Rotor Tower	2,100	
Tiedowns	1,100	
Transmission and Drive Train	3,430	
Electricals	1,290	
Miscellaneous	180	
Direct Cost		$ 9,600
Production Overhead @ 7.9%		$ 950
Corporate Overhead @ 5.1%		614
Profit @ 7.2%		866
Selling Price (F.O.B. Plant):		$12,030
Typical State/Local Sales or Use Tax		$ 481
Typical Distributor Cost/Profit @ 6%		722
Typical Delivery Cost		250
Typical On-Site Costs		3,500
Estimated Installed Cost to Owner		$16,983

SANVAWT, INC. (Scenario #2d)
DISTRIBUTION AND ON-SITE WORK
30 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 30 kW = $516.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$2,100
(2) Subsystem Erection	1,400
Total On-Site Costs	$3,500

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
30 kW	8,420#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2d)
Cost Estimate and Selling Price
120 kW Vertical Axis Wind Turbine

(250 Units/Year)

VAWT Description:

Peak Electrical Capacity	120 kW
Wind Velocity @ Peak Capacity	30 mph
Average Electrical Output @ 15 mph	28.5 kW
Annual Energy Output @ 15 mph Site	250,000 kWh

Production Cost Elements:

Subsystems and Components		
Rotor Blades	$ 8,000	
Rotor Tower	3,836	
Tiedowns	2,300	
Transmission and Drive Train	15,800	
Electricals	5,639	
Miscellaneous	425	
Direct Cost		$36,000
Production Overhead @ 7.9%		$ 3,564
Corporate Overhead @ 5.1%		2,301
Profit @ 7.2%		3,248
Selling Price (F.O.B. Plant):		$45,113
Typical State/Local Sales or Use Tax		$ 1,805
Typical Distributor Cost/Profit @ 6%		2,707
Typical Delivery Cost		250
Typical On-Site Costs		18,000
Estimated Installed Cost to Owner		$67,874

SANVAWT, INC. (Scenario #2d)
DISTRIBUTION AND ON-SITE WORK
120 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 120 kW = $1,912.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$ 8,000
(2) Subsystem Erection	10,000
Total On-Site Costs	$18,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
120 kW	25,160#	1 @ 250 miles	$250

SANVAWT, INC. (Scenario #2d)
Cost Estimate and Selling Price
200 kW Vertical Axis Wind Turbine

(130 Units/Year)

VAWT Description:		
Peak Electrical Capacity	220 kW	
Wind Velocity @ Peak Capacity	31 mph	
Average Electrical Output @ 15 mph	56.3 kW	
Annual Energy Output @ 15 mph Site	493,000 kWh	
Production Cost Elements:		
Subsystems and Components		
Rotor Blades	$13,600	
Rotor Tower	11,200	
Tiedowns	5,500	
Transmission and Drive Train	24,050	
Electricals	9,300	
Miscellaneous	1,350	
Direct Cost		$ 65,000
Production Overhead @ 7.9%		$ 6,435
Corporate Overhead @ 5.1%		4,154
Profit @ 7.2%		5,865
Selling Price (F.O.B. Plant):		$ 81,454
Typical State/Local Sales or Use Tax		$ 3,258
Typical Distributor Cost/Profit @ 6%		4,887
Typical Delivery Cost		750
Typical On-Site Costs		28,000
Estimated Installed Cost to Owner		$118,349

SANVAWT, INC. (Scenario #2d)
DISTRIBUTION AND ON-SITE WORK
200 kW Vertical Axis Wind Turbine

State and Local Sales and Use Taxes:

Although many governmental agencies are waiving local taxes as incentive for installation of energy conserving equipment, these estimates assume an average 4% tax on the F.O.B. plant price of each VAWT. Taxes on 200 kW = $3,460.

Site Improvement and VAWT Erection Costs:

For purposes of these estimates, the site is assumed to be owned by a non-utility VAWT customer. Although some customers may choose to prepare the site and install the VAWT themselves, these estimates assume on-site work will be performed by an independent local contractor paying average non-union field construction wages.

Item	Total
(1) Turbine Foundation, Including Grading, Tiedown Footings and Surveying	$14,000
(2) Subsystem Erection	14,000
Total On-Site Costs	$28,000

Shipping Weights and Delivery Costs:

VAWT Capacity	Weight	Truckloads	Delivery Cost
200 kW	46,770#	3 @ 250 miles	$750

C2 - Addendum to the Alcoa Executive Summary
(For the Single Model Production Scenarios)

10 kW SANVAWT
QUANTITY PRICE ESTIMATE

Cost Elements	ANNUAL QUANTITIES			
	$5 Million	$10 Million	$25 Million	$50 Million
	4.32 MW	10.17 MW	30.00 MW	67.16 MW
	480 Units	1,130 Units	3,330 Units	7,460 Units
Rotor Blades	$ 600	$ 580	$ 530	$ 480
Rotor Tower	1,750	1,690	1,450	1,300
Tiedowns	520	500	490	480
Transmission/Drive Train	2,300	2,250	2,010	1,910
Electricals	1,310	1,260	1,140	1,030
Miscellaneous	120	120	110	100
Total Direct	$ 6,600	$6,400	$5,730	$5,300
Production Overhead	$ 1,350	$ 930	$ 730	$ 580
Corporate Overhead	1,250	680	440	340
Profit	1,200	840	600	480
Selling Price	$10,400	$8,850	$7,500	$6,700

30 kW SANVAWT

QUANTITY PRICE ESTIMATE

	ANNUAL QUANTITIES			
	$5 Million	$10 Million	$25 Million	$50 Million
	9.38 MW	22.17 MW	65.22 MW	144.93 MW
Cost Elements	310 Units	740 Units	2,175 Units	4,831 Units
Rotor Blades	$ 1,520	$ 1,480	$ 1,330	$ 1,265
Rotor Tower	2,350	2,200	1,870	1,730
Tiedowns	1,100	1,100	1,090	1,050
Transmission/Drive Train	3,520	3,350	3,180	2,980
Electricals	1,400	1,290	1,155	1,085
Miscellaneous	200	180	160	150
Total Direct	$10,090	$ 9,600	$ 8,785	$ 8,260
Production Overhead	$ 2,080	$ 1,490	$ 1,115	$ 815
Corporate Overhead	1,970	1,090	680	530
Profit	1,860	1,350	920	745
Selling Price	$16,000	$13,530	$11,500	$10,350

120 kW SANVAWT
QUANTITY PRICE ESTIMATE

	ANNUAL QUANTITIES			
	$5 Million	$10 Million	$25 Million	$50 Million
	10.12 MW	23.58 MW	69.44 MW	154.24 MW
Cost Elements	84 Units	196 Units	580 Units	1,285 Units
Rotor Blades	$ 8,150	$ 8,000	$ 7,200	$ 6,610
Rotor Tower	4,150	3,820	3,500	3,200
Tiedowns	2,400	2,300	2,200	2,100
Transmission/Drive Train	16,200	15,800	14,420	13,900
Electricals	6,100	5,700	5,330	4,900
Miscellaneous	400	380	350	330
Total Direct	$37,400	$36,000	$33,000	$31,040
Production Overhead	$ 7,720	$ 5,670	$ 4,190	$ 3,075
Corporate Overhead	7,290	4,140	2,550	1,985
Profit	6,890	5,090	3,460	2,800
Selling Price	$59,300	$50,900	$43,200	$38,900

200 kW SANVAWT

QUANTITY PRICE ESTIMATE

	ANNUAL QUANTITIES			
	$5 Million	$10 Million	$25 Million	$50 Million
	10.22 MW	23.71 MW	69.71 MW	154.95 MW
Cost Elements	46 Units	108 Units	317 Units	704 Units
Rotor Blades	$14,400	$13,600	$12,400	$11,700
Rotor Tower	11,700	11,200	10,300	9,470
Tiedowns	5,500	5,300	5,100	5,000
Transmission/Drive Train	25,500	24,050	22,680	21,320
Electricals	9,500	9,300	8,800	8,300
Miscellaneous	1,300	1,250	1,000	860
Total Direct	$67,900	$64,700	$60,280	$56,650
Production Overhead	$13,990	$10,300	$ 7,655	$ 5,610
Corporate Overhead	13,230	7,500	4,655	3,620
Profit	12,480	10,300	6,310	5,110
Selling Price	$107,600	$92,800	$78,900	$70,990

500 kW SANVAWT

QUANTITY PRICE ESTIMATE

	ANNUAL QUANTITIES			
	$5 Million	$10 Million	$25 Million	$50 Million
	8.50 MW	20.00 MW	58.54 MW	129.73 MW
Cost Elements	18 Units	42 Units	122 Units	270 Units
Rotor Blades	$ 24,530	$ 23,300	$ 21,670	$ 20,290
Rotor Tower	33,200	29,880	26,360	24,400
Tiedowns	14,500	14,000	12,600	12,350
Transmission/Drive Train	55,410	54,500	51,670	49,690
Electricals	33,900	30,500	28,500	27,150
Miscellaneous	2,850	2,800	2,700	2,650
Total Direct	$164,390	$154,980	$143,500	$136,530
Production Overhead	$ 36,735	$ 26,900	$ 19,885	$ 14,615
Corporate Overhead	39,575	26,900	17,015	14,615
Profit	41,800	31,200	24,600	19,240
Selling Price	$282,500	$240,000	$205,000	$185,000

1600 kW SANVAWT

QUANTITY PRICE ESTIMATE

	ANNUAL QUANTITIES			
	$5 Million	$10 Million	$25 Million	$50 Million
	9.85 MW	25,58 MW	71.17 MW	158.10 MW
Cost Elements	6 Units	16 Units	44 Units	99 Units
Rotor Blades	$ 97,000	$ 90,000	$ 83,000	$ 78,900
Rotor Tower	96,000	88,000	79,000	73,400
Tiedowns	40,000	38,000	35,700	34,900
Transmission/Drive Train	177,500	160,000	148,000	142,000
Electricals	53,000	45,000	40,500	37,400
Miscellaneous	9,000	8,000	7,200	6,800
Total Direct	$472,500	$429,000	$393,400	$373,400
Production Overhead	$105,620	$ 73,070	$ 54,510	$ 39,985
Corporate Overhead	113,690	73,070	46,650	39,985
Profit	120,190	85,860	67,440	52,630
Selling Price	$812,000	$661,000	$562,000	$506,000

C3 - Alcoa Backup Data Summary

Section 1

Multiple Unit Equipment Cost & Weight Data

The raw cost data for the various mechanical and electrical equipment for the six SANVAWT systems has been summarized in tables 1.1, and 1.2. This cost data represents the least cost for items produced in quantities of 10 and upward.

This summary provides an excellent indication of the items that most influence the final cost of the system. It was used throughout the completion of the study to direct the cost procurement efforts and highlight required system design changes.

The "bottom line" prices shown on these tables should not and cannot be compared with those appearing in the Business Scenarios #1 and #2 in the Executive Summary of this report because these costs include component vendors labor rates and profits. This summary is only presented as a means of showing the relative cost importance of the various system components.

VERTICAL AXIS WIND TURBINES
ALCOA/SANDIA LABORATORIES PARAMETRIC OPTIMIZATION STUDY

Table 1.1 - EQUIPMENT COST AND WEIGHT DATA FOR SCENARIO #1

NOMINAL RATING (KW)	120				200				500				1600			
PEAK RATING (KW)	120				220				480				1600			
ANNUAL OUTPUT (KW-HR/RPM)	250,000/54				493,000/41				1,070,000/31				3,000,000/23			
DESCRIPTION	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW
Mechanical Equipment																
Blade																
1. Blade (material)	6,830	14	3,540	14	11,990	13	5,840	12	22,510	12	11,620	11	50,570	10	25,990	9
2. Blade end clamp and filler (material)	3,970	8	1,300	5	5,840	7	1,920	3	16,500	8	5,400	5	49,200	10	16,260	5
3. Blade joint insert (material)	140	-	307	1	240	-	832	2	1,460	1	1,458	1	2,400		4,832	2
4. Blade bending and machining	2,200	4	N/A	N/A	2,400	3	N/A	N/A	9,000	5	N/A	N/A	19,600	4	N/A	N/A
Rotor																
5. Rotor Tower	6,400	13	7,360	29	16,740	19	13,270	28	29,630	15	32,660	30	80,360	16	100,870	33
6. Universal Joint	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7. Upper Bearing Assembly	700	1	247	1	1,840	2	473	1	5,450	3	1,130	1	19,940	4	3,480	1
8. Lower Bearing Assembly	700	1	247	1	1,840	2	473	1	5,450	3	1,130	1	19,940	4	3,480	1
Drive Train																
9. Transmission	12,770	26	3,000	12	19,570	22	6,000	13	40,000	21	17,000	16	105,670	21	51,000	17
10. Low Speed Coupling	1,240	2	1,052	4	2,480	3	2,070	4	5,280	3	6,336	6	17,600	4	21,120	7
11. High Speed Coupling	80	-	35		110	-	35	-	130		95		310		150	
12. Structural Support	1,600	3	2,700	11	2,650	3	4,700	10	4,100	2	7,300	7	7,700	1	14,000	5
13. Brakes	700	1	342	1	750	1	410	1	900		610	1	2,400		1,010	
14. Clutch	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8,000	2	3,200	1
15. Differential	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tiedowns																
16. Cable Tiedowns	3,520	7	2,405	10	7,770	9	6,094	13	15,510	8	12,387	11	47,520	10	36,956	12
17. Cable Tensioning Devices	190	4	88		500	1	189	-	79	-	252		2,880		975	
Miscellaneous																
18. Miscellaneous Equipment	820	2	450	2	1,500	2	850	21	3,120	2	1,820	2	8,520	2	4,240	1
Subtotal (items 1 through 18)																
19. Mechanical Equipment Subtotal	41,860	86	23,073	91	76,220	86	43,150	92	159,830	83	99,198	92	442,610	89	287,563	94

VERTICAL AXIS WIND TURBINES
ALCOA/SANDIA LABORATORIES PARAMETRIC OPTIMIZATION STUDY

Table 1.1 (continued) - EQUIPMENT COST AND WEIGHT DATA FOR SCENARIO #1

NOMINAL RATING (KW)	120 (continued)				200 (continued)				500 (continued)				1600 (continued)			
PEAK RATING (KW)	120				220				480				1600			
ANNUAL OUTPUT (KW-HR/RPM)	250,000/54				493,000/41				1,070,000/31				3,000,000/23			
DESCRIPTION	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW
Electrical Equipment																
20. Generator	4,000	8	1,500	6	6,160	7	1,550	3	16,500	8	3,900	4	32,000	6	12,500	4
21. Power Cabinets	3,130	6	810	3	6,570	7	2,070	5	17,020	9	4,860	4	21,600	4	6,170	2
22. Navigational Lighting	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,000	1	1,000	
Subtotal (items 20 through 22)																
23. Electrical Equipment Subtotal	7,130	14	2,310	9	12,730	14	3,620	8	33,520	17	8,760	8	56,600	11	19,670	6
Total (Line 19 plus 23)																
24. Total Equipment Cost	48,990	100			88,950	100			193,350	100			499,210	100		
25. Total Equipment Weight			25,383	100			46,770	100			107,958	100			307,233	100
COST COMPARISON																
26. $/KW	408				404				402				312			
27. $/#			1.95				1.90				1.79				1.62	

Notes:

1) This table is a summary of raw costing and weight data for the VAWT's that make up Scenario #1 in the executive summary of this report. These costs include manufacturers overhead and profit and exclude mark-up of the turbine manufacturer. As such, these costs cannot be directly related to the cost in the executive report. They are presented to indicate the relative cost effect of the major components.
2) The nominal power ratings, peak power ratings and annual output data shown were provided by Sandia Laboratories. The data reflects the power generation of the respective unit located in a 15 mph wind regime.
3) The vertical thrust of the turbine is supported by a structural platform over the transmission. This arrangement includes a thrust bearing in the support structure, a low speed flexible coupling, and transmission sized for the power requirements.
4) The VAWT systems in this Scenario are based on full voltage start of an 1800 rpm, 460V induction motor direct coupled to the transmission.
5) All weights shown are approximate weights in pounds.
6) No shipping charges from the equipment supplier to the assembly plant site are included.
7) No automatic controls are included in this estimate.
8) Unless noted otherwise in the comments referenced in note 9, no costs to assemble the components in the system are included.
9) For comments on the items listed in this table, see the respective item number under item comments for Tables 1.1 and 1.2.

VERTICAL AXIS WIND TURBINES
ALCOA/SANDIA LABORATORIES PARAMETRIC OPTIMIZATION STUDY

Table 1.2 - EQUIPMENT COST AND WEIGHT DATA FOR SCENARIO #2

NOMINAL RATING (KW)	10				30				120				200			
PEAK RATING (KW)	9				30				120				220			
ANNUAL OUTPUT (KW-HR/RPM)	16,400 (174)				60,000 (100)				250,000 (54)				493,000 (41)			
DESCRIPTION	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW
Mechanical Equipment																
Blade																
1. Blade (material)	150	2	120	3	900	9	640	9	6,830	14	3,540	14	11,990	13	5,840	12
2. Blade End Clamp and Filler (material)	170	2	34	1	610	5	184	3	3,970	8	1,300	5	5,840	7	1,920	3
3. Blade Joint Insert (material)	N/A	N/A	N/A	N/A	20	2	136	2	140		307	1	240		832	2
4. Blade Bending and Machining	400	5	N/A	N/A	700	5	N/A	N/A	2,200	4	N/A	N/A	2,400	3	N/A	N/A
Rotor																
5. Rotor Tower	1,810	21	523	14	3,040	23	2,134*	28	6,400	13	7,360	29	16,740	19	13,270	28
6. Universal Joint	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7. Upper Bearing Assembly	370	4	158	4	380	3	162	2	700	1	247	1	1,840	2	473	1
8. Lower Bearing Assembly	370	4	158	4	380	3	162	2	700	1	247	1	1,840	2	473	1
Drive Train																
9. Transmission	1,590	19	200	5	2,420	18	600	8	12,770	26	3,000	12	19,570	22	6,000	13
10. Low Speed Coupling	240	3	48	1	400	3	145	2	1,240	2	1,052	4	2,480	3	2,070	4
11. High Speed Coupling	60	1	20	1	60	-	20		80		35		110		35	
12. Structural Support	850	10	1,400	37	850	6	1,400	19	1,600	3	2,700	11	2,650	3	4,700	10
13. Brakes	130	2	50	1	190	1	106	1	700	1	342	1	750	1	410	1
14. Clutch	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Differential	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tiedowns																
16. Cable Tiedowns	590	7	166	4	1,190	9	519	7	3,520	7	2,405	10	7,770	9	6,094	13
17. Cable Tensioning Devices	70	1	15		150	1	38	-	190	4	88		500	1	189	
Miscellaneous																
18. Miscellaneous Equipment	140	2	60	2	230	2	145	2	820	2	450	2	1,500	2	850	2
Subtotal (Items 1 through 18)																
19. Mechanical Equipment Subtotal	6,940	83	2,952	77	11,520	87	6,391	85	41,860	86	23,073	91	76,220	86	43,150	92

*Corrected 79/03/15

VERTICAL AXIS WIND TURBINES
ALCOA/SANDIA LABORATORIES PARAMETRIC OPTIMIZATION STUDY

Table 1.2 (Continued) - EQUIPMENT COST AND WEIGHT DATA FOR SCENARIO #2

NOMINAL RATING (KW)	10 (continued)				30 (continued)				120 (continued)				200 (continued)			
PEAK RATING (KW)	9				30				120				220			
ANNUAL OUTPUT (KW-HR/RPM)	16,400/174				60,000/100				250,000/54				493,000/41			
DESCRIPTION	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW	COST	%TEC	WEIGHT	%TEW
Electrical Equipment																
20. Generator	250	3	200	5	500	4	430	6	4,000	8	1,500	6	6,160	7	1,550	3
21. Power Cabinets	1,180	14	670	18	1,200	9	690	9	3,130	6	810	3	6,570	7	2,070	5
22. Navigational Lighting	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subtotal (Items 20 through 22)																
23. Electrical Equipment Subtotal	1,430	17	870	23	1,700	13	1,120	15	7,130	14	2,310	9	12,730	14	3,620	8
Total (Items 19 plus 23)																
24. Total Equipment Cost	8,370	100			13,220	100			48,990	100			88,950	100		
25. Total Equipment Weight			3,822	100			7,511	100			25,383	100			46,770	100
COST COMPARISON																
26. $/KW	930				440				408				404			
27. $/#			2.19				1.76*				1.95				1.90	

Notes:
1) This table is a summary of raw costing and weight data for the VAWT's that make up Scenario #2 in the executive summary of this report. These costs include manufacturers overhead and profit and exclude mark-up of the turbine manufacturer. As such, these costs cannot be directly related to the cost in the executive report. They are presented to indicate the relative cost effect of the major components.
2) The nominal power ratings, peak power ratings and annual output data shown were provided by Sandia Laboratories. The data reflects the power generation of the respective unit located in a 15 mph wind regime.
3) The vertical thrust of the turbine is supported by a structural platform over the transmission. This arrangement includes a thrust bearing in the support structure, a low speed flexible coupling, and transmission sized for the power requirements.
4) The 120 and 200 KW unit costs are based on full voltage start of an 1800 rpm, 460V induction motor direct coupled to the transmission. The 500 KW unit cost is based on reduced voltage starting of an 1800 rpm, 460V induction motor direct coupled to the transmission. The 1600 KW unit cost is based on full voltage start of an 1800 rpm, 4160V induction motor coupled to the transmission by a mechanical clutch.
5) All weights shown are approximate weights in pounds.
6) No shipping charges from the equipment supplier to the assembly plant site are included.
7) No automatic controls are included in this estimate.
8) Unless noted otherwise in the comments referenced in note 9, no costs to assemble the components in the system are included.
9) For comments on the items listed in this table, see the respective item number under item comments for Tables 1.1 and 1.2.

*Corrected 79/03/15

Item Comments for Tables 1.1 and 1.2

1. Blade Material - This cost assumes total quantity is released for shipment at one time. The prices shown are for maximum production quantities. Set-up charge has been prorated over entire quantity. For details of blade characteristics, see table of standard blade profiles. Blade lengths and section breakdowns are shown on Alcoa drawing B-201982-ED.
2. Blade End Clamp and Filler - These items are priced as castings having a right and left section as shown on Alcoa drawing B-201990-ED. Included is the pattern cost prorated over the entire production quantity for maximum production Scenario.
3. Blade Joint Inserts - Pricing for this material was based on blade splice inserts shown on Figures 3.9.2 of this appendix.
4. Blade Bending and Machining - This item is a labor charge for cutting blade sections to length, bending, fitting blade inserts, match drilling, and end preparation prior to shipment. This operation includes shop assembly of items 1 through 3.
5. Rotor Tower - This cost includes fabrication and fitting of all components of the turbine tower or rotor from the bottom end adapter to the lightning tower with the exception of the top bearing assembly. Also included is the end adapter for the blade connection. The items included are shown on Alcoa drawings B-201974-ED, B-201981-ED, B-201976-ED, B-201979-ED, B-201980-ED and B-201981-ED. These drawings were established from Sandia's drawings of the 200, 500 and 1600 KW units. Not included in this cost is final painting and sectional assembly for shipment.
6. Universal Joint - The vertical support arrangement selected does not require the use of a thrust carrying universal joint. Flexible connection is made using flex-gear couplings. Item 10.

7 & 8. Upper and Lower Bearing Assemblies - The bearings shown in this layout are Torrington Spherical Roller Thrust Bearings. The assemblies are shown on Alcoa drawing B-201983-ED. For pricing purposes the same assembly is used for both the upper and lower bearings. Orientation of the lower bearing will be the reverse of the assembly shown on the referenced drawing.

9. Transmissions - The transmissions in these systems are all right-angle gear boxes sized to meet applied power requirements. They do not have the ability to carry excessive thrust loads. The costs reflected for the 10 and 30 KW units are for Hansen Transmissions, Inc., speed changers. The costs for the 120, 200, 500 and 1600 KW units are for XTek speed changers. In all cases, the output speed is 1800 rpm. Power transmission requirements are shown on Alcoa drawing B-201978-ED.

10. Low Speed Coupling - Coupling of the turbine rotor and low speed transmission shaft is made with two Falk vertical flex-gear couplings and intermediate shafting.

11. High Speed Coupling - High speed couplings are Koppers Series H flex-gear couplings.

12. Structural Support - Costs shown for this structure were provided by Alcoa Pittsburgh construction. Costs include fabrication in the shop and grouted in place as a unit in the field.

13. Brakes - Brakes for these units are standard Goodyear industrial disc and caliper brakes. Included in this cost is the disc, caliper, and an estimate for support bracket. Brake torque and energy adsorption requirements are shown on Alcoa drawing B-201986-ED.

14. Clutch - The only unit requiring a clutch is the 1600 KW unit. Soft starting of the 500 KW unit is accomplished with reduced voltage start-up.

15. Differential - Differentials were not utilized on these units.

16. Cable Tiedowns - The tiedown cable costing includes cable and end fittings as an assembly from the cable supplier. The cable assemblies are shown on Alcoa drawing B-201987-ED.

17. Cable Tensioning Device - The cost shown here is based on an in-line tensioning device incorporating cable adjustment and a hydraulic cylinder for measuring the setting tension.

18. Miscellaneous Equipment - Included in this item is sufficient costs to provide miscellaneous small mechanical components such as nuts, bolts, various fasteners, lightning protection circuit slip rings, means of brake actuation, etc. Assumed 2% of items 1 through 17.

19. Mechanical Equipment Subtotal - Sum of items 1 through 18.

20. Generator - The generator cost for the 10, 30, 120, 200 and 500 KW systems is for an 1800 rpm, 460V induction motors. The generator for the 1600 KW unit is an 1800 rpm, 4160V induction motor.

21. Power Cabinets - Includes all components required for supply of power to the generator as well as motor protection. See table of electrical components for parts included. Main line power source is assumed as 460V, 3 phase.

22. Obstruction Lighting - Obstruction lighting is required on the 1600 KW unit as it exceeds the FAA 200-feet limit.

23. Electrical Equipment Subtotal - Sum of items 20 through 22.

24. Total Equipment Cost - Sum of items 19 plus 23.

25. Total Equipment Weight - Sum of items 19 plus 23.

26. $/KW - This is the ratio of total equipment cost to the peak power rating.

27. $/# - Ratio of total equipment cost to the total equipment weight.

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