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RENEWABLE ENERGY RESOURCES
FIELD TESTING

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APPLICATION REVIEW FOR FIELD TEST #11

WIND FARM AT RAS GHAREB

MAY 1986

FINAL

Prepared for

Egyptian Electricity Authority
Cairo, Egypt

U.S. Agency for International Development
USAID Mission: Cairo, Egypt

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FOREWARD
APPLICATION REVIEW

The Egyptian Electricity Authority (EEA), United States Agency for International Development (USAID/Cairo), and a group of U.S. consultants form a team responsible for conducting field test demonstration projects for eleven renewable energy applications in Egypt. These demonstration projects include the use of photovoltaic, wind and solar thermal systems for water pumping, ice making, desalination, industrial process heat and grid connected electricity generation. The specific objectives of the 4-year program are: (1) to demonstrate the viability of renewable energy technologies in Egypt, (2) to comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision making, and (3) to establish the infrastructure necessary to ensure that renewable energy technologies, which have proven successful, are available for widespread use in Egypt.

Three of the eleven potential field test demonstration projects are wind energy system applications. Each of the field tests contains seven generic tasks: Technology Review, Application Review, Conceptual Design, Preparation of a Statement-of-Work for a Tender Document, Proposal Evaluation, Supervision of Hardware Installation and Performance Evaluation. The Application Review for one of these three field tests, a grid-connected wind farm, is presented in this document.

The proposed wind farm is sited near Ras Ghareb on the Red Sea and will consist of multiple, interconnected turbines with a total peak power of approximately 250 kW. The system is designed to operate in a fuel-saver mode for an existing power station and provide electricity to an existing transmission grid. This Application Review is the key document on which a decision to proceed further with a particular field test will be based. The Review summarizes an evaluation of the proposed field test location, user requirements, wind

resource assessment and the wind energy system technology necessary to successfully implement the grid-connected wind farm application.

This document is subtask 3.11.1 of the field test requirements under Contract AID 263-123C-00-4069-00, Task Area 3. The recommendations made in this document are based on the technical merit of the application. The results from Task 2.1, Economic/Market Assessment address other factors such as economics, market size and social/institutional aspects that may impact the potential for widespread implementation of wind farms in Egypt. The Task 2.1 results are provided in a separate document.

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1.0 EXECUTIVE SUMMARY

1.1 Objectives of the Field Test and the Application Review

There are a number of key factors that provide the contents for Application Reviews and support the evaluation of the desirability to proceed with a particular field test. The first factor is the degree to which the field test contributes to the objectives of the overall Renewable Energy Field Testing (REFT) Project. The Project has broad objectives to investigate selected renewable energy options:

1. Comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision-making for technologies and applications;

2. Develop and sustain an Egyptian renewable energy infrastructure through establishment of data bases, information systems and organizations that effectively serve both the public and private sectors;

3. Design, install, operate and evaluate a series of renewable energy field tests which utilize commercially available technologies in applications having potential for widespread use in Egypt.

4. Conduct a formal management and technical training program, both on-the-job and specialized, and establish an intensive information dissemination program.

The proposed field test for a small wind farm interconnected with a local grid distribution system at Ras Ghareb is based on three observations, (1) the significant growth in the past few years in the wind energy system industry and in particular the success of wind farms for the generation of electricity in the U.S., (2) a review of wind energy resource data in Egypt, suggesting that several large regions of the country appear to have a sufficient resource to allow consideration of wind farm as part of a system for the generation of electricity, and (3) evidence of a technical and institutional capability within the country that can be strengthened to allow for widespread development of this technology.

An assessment of the contribution of this specific field test to the REFT Project objectives must consider the criteria necessary for a successful demon-

stration of any grid-connected wind farm. These criteria are comprehensively listed below, although not necessarily in the order of importance.

1. Current and future user needs
2. Size and stability of the local electrical grid
3. Evidence of a viable wind resource
4. Availability of proven and reliable commercial systems
5. Appropriate site characteristics and infrastructure for installation
6. Capability of the host organization for successful operation and maintenance of the systems
7. Potential for widespread use including social, economic and institutional aspects

The following paragraphs summarize the findings of various studies and analyses addressing these criteria.

1.2 Current and Future User Requirements

The village of Ras Ghareb is supplied with electrical power from two power plants, one operated and maintained by the General Petroleum Company (GPC) and one by the Egyptian Electricity Authority (EEA). The GPC power plant has two 3-MW Sulzer gas turbines to meet an average 2.7 MW load demand. The load consists of mostly oil drilling and pumping operations but does include about ten percent of the village power demand. As of May 1985, the EEA power plant consisted of six diesel generators that supplied approximately 1.1 MW of power to satisfy about 90 percent of the village load. Recently a new Sulzer 5-MW gas turbine has come on-line and the diesel plant is in the process of being shut down. A second Sulzer 5-MW gas turbine is collocated with this one, but it is not presently in operation. This power generation mix provides a stable, reliable source of electricity for the Ras Ghareb region.

A very good grid distribution system interconnects the various outlying oil fields and the village residences with the respective power plants. There are two distribution systems in Ras Ghareb, a 6.6 KV line for the GPC and a 11 KV line for the EEA. Transmission cables are both overhead and underground.

The GPC is planning for a significant growth in the next few years in

the industrial load demand in the Ras Ghareb region as new oil fields are developed and interconnected with the existing grid. This growth will increase the baseline demand to more than 3 MW. In order to maintain a required 100 percent power generation back-up capacity, the GPC is installing a 5-MW Japanese gas-fired turbine. This new turbine is currently undergoing check-out tests. It may become the primary power source for GPC with the two existing 3-MW Sulzer (1976 Swiss design) turbines used for back-up.

1.3 Size and Stability of the Local Grid

The electrical demand at Ras Ghareb consists of an industrial-type load of motors and pumps to supply required power for oil drilling and oil production in the area (approximately 2.5 to 3.0 megawatts) and a typical residential-type load for power to lights and small appliances for the village itself (approximately 1.0 to 1.5 megawatts). Discussions with EEA and GPC personnel revealed that the load demand in general is constant and continuous. This results from the large baseline demand required on a 24-hour basis to run the oil production operation.

The EEA is cognizant of the expected growth in electrical demand projected for the Red Sea coast. EEA intends to monitor the performance of this wind farm demonstration project to assess the potential for additional wind farms in the region. If wind power is a viable alternative energy source, the EEA would re-allocate existing gas turbine generators to balance regional electricity generating capacity as wind generated power comes on-line.

In summary, a large, stable power generation/distribution grid exists at Ras Ghareb which should be able to interface with a 250 kilowatt wind farm. There also appears to be sufficient flexibility in the existing power generation mix to incorporate wind systems as they come on-line.

1.4 The Wind Resource at Ras Ghareb

There are two major historical sources of wind characteristics data for the Ras Ghareb area. One source consists of data gathered by Oklahoma State University for the Egyptian Wind Energy Resource Study. The data (four months) were published in November 1979. The other source is the "Harbor Station" which is a meterological station that has been recording wind velocity and direction for at least the past five years. In general, these measurements indicate an average wind velocity of 6.4 (4 month average) to 7.3 (annual average) meters/ second (1978 Oklahoma State data and 1983 Harbor Station data respectively). This is a sufficient wind velocity for the generation of electricity using wind turbines.

Equally important with the magnitude of the wind resource at a specific site is the hourly variability of the wind if a specific load demand profile is to be satisfied. The annual average diurnal wind velocity measured at the Harbor Station at Ras Ghareb for 1983 indicates a slight average increase throughout the morning hours and a slight average decrease throughout the afternoon with a minimum occurring about sunset. The greater detail in the monthly averaged diurnal data over a single month shows a more marked increase in wind speed throughout the morning hours and a rather steep decline in the late afternoon. This will result in a similar power fluctuation when wind turbines are used to generate electricity. This variation is acceptable for the Ras Ghareb application because the wind energy electricity generation component of the power generation system is only a small percentage of a relatively large and constant load demand.

In general, a wind resource is very site dependent, both spatially and temporally. Therefore, it is very important that wind velocity data be validated and collected as near to the actual turbine site as possible and for an extended period of time. In support of Field Test #11, USAID/Cairo has contracted with Battelle Pacific Northwest Laboratories to conduct a wind resource assessment

of Egypt. Measurements have been recorded at the proposed wind farm site since March 1985. These data will be analyzed for a period of one year.

For the period April - September 1985, these data indicate an average wind speed of 9.2 meters/second at 10 meters above ground level and 9.6 meters/second at 20 meters above ground level. This is an excellent wind resource that is comparable to areas in California where commercial installations of wind turbines are found.

In summary, the Ras Ghareb region has an historical wind measurement data base that is sufficient to establish the location as a high wind area. On-going measurements over the past 6-months support this conclusion. From a wind resource perspective, Ras Ghareb is an excellent site for a wind farm.

1.5 Availability of Proven and Reliable Commercial Systems

Due to the intermittent nature of the wind, the generation of electricity from the wind will vary considerably with time. As a result, wind generated electricity should supply only a small percentage of a given load. Wind turbines are controlled so that they run at a constant rotor speed but rapid fluctuations in wind speed can cause voltage and frequency swings that would be unacceptable to a user if the baseline grid system is not large enough to absorb them. In general, the size of a wind farm should be limited to between 10 and 15 percent of a user's load demand. For the Ras Ghareb application, this results in a wind farm with a peak power of approximately 250 to 400 kilowatts.

All of the hardware systems required to complete a grid-connected wind farm application are technologically mature, of proven operation and commercially available. A separate Technology Review document for this field test was published in January 1986. A more general discussion of wind system technology is presented in the Wind Energy Technology Reference Notebook published in June 1985.

A preliminary wind farm conceptual design sizing study was completed in August 1985. Based on the results of this study and consideration of the overall REFT Project objectives, the first wind farm field test demonstration in Egypt should be an installation of a reasonable number of interconnected and commonly controlled turbines connected to an existing electrical grid. Therefore, the conclusion is reached that the Ras Ghareb wind farm should consist of between 5 and 15 wind turbines each producing between 20 and 65 kilowatts peak power for a total of approximately 250 kilowatts.

Other important design considerations for wind farms include: (1) balance between the cost of low voltage conductors and transformers; (2) the number of turbines connected to each transformer; (3) turbine spacing; (4) line loss; and (5) land cost. For example, economies of scale for large transformers are offset by the numbers and length of conductors required to link with multiple turbines. Close turbine spacing shortens conductor lengths, permits more turbines per transformer, and reduces land costs. These advantages can be offset, however, by reduced energy capture from close spacing. Little information is available on these tradeoffs. In current U.S. wind farm designs, engineering optimizations are limited and design alternatives with the lowest initial cost are usually selected. These aspects of system design must be evaluated for each respondent to the tender document.

In summary, wind system hardware is proven and available from numerous sources. A 250 kilowatt peak wind farm appears to be a reasonable and acceptable size for the Ras Ghareb distribution grid.

1.6 Salient Issues and Needs

1.6.1 Additional Wind Resource Measurements

For micrositing of wind turbines within a wind farm, it is important that wind

characteristic measurements be made as nearly as possible at the nominal hub height of the turbines expected to be used. In general, U.S. wind turbines are installed on 24.4 meter to 30 meter towers. Additional data will be collected throughout the proposed wind farm area at a 30 meter height if at all possible.

1.6.2 Civil Work and Site Preparation

The proposed wind farm site at Ras Ghareb is located along a ridge line at an elevation of approximately 42 meters above sea level. The site is in a treeless coastal desert region and presents an unobstructed view to the prevailing northwest winds. Site preparation in the form of civil work to level the site will be required. An access road capable of transporting heavy equipment (turbines, towers, cement trucks, cranes) will also be required. A soil analysis should be completed as soon as possible to provide data on soil strength so that an assessment on the specifications and cost of the road can be made. Also soil strength data will be required for the preparation of the statement-of-work so that bidding contractors can accurately cost the turbine/tower foundations. A building(s) to house the wind farm control systems, performance monitoring instrumentation and some amount of spare parts/maintenance equipment will also be required.

1.6.3 Infrastructure Considerations

A key factor in the success of a wind farm field test demonstration is the ability of the host organization to successfully operate and maintain the system. This is especially true for this field test of the first operating wind farm in Egypt and the first electricity generating wind turbines along the Red Sea coast. The GPC engineers and technicians have constructed numerous oil drilling rigs. They are accustomed to maintaining large rotating machinery, both megawatt size gas turbines and numerous diesel engines. They also have installed and continue to maintain their own electrical transmission grid,

including transformers and switch gear. With appropriate training in the operation and maintenance of wind turbines and associated wind farm hardware (which is a part of this field test), it is expected that GPC personnel could operate and maintain a wind farm.

1.7 Status of Agreements and Responsible Agencies

A review of all relevant agreements between USAID, the EEA and all participating entities should be undertaken to insure that the decision to proceed or not with this field test is based on an accurate appraisal of the existing situation. This includes concurrence by all parties that the field test as specified in this Application Review is acceptable, that all responsibilities of participants are clearly specified and understood, and that required site preparation and civil works can be completed in a timely fashion.

1.8 Conclusions and Recommendation

The findings in this Application Review support a strong recommendation that a grid-connected windfarm of approximately 250 kilowatts should be designed, purchased and installed at Ras Ghareb. All the necessary criteria for a successful wind farm installation appear to be satisfied at the Ras Ghareb location as follows:

1. The current and future electricity needs of the Ras Ghareb region are supplied by a stable grid that should be able to accept a 250 kilowatt wind farm.

2. The wind resource is excellent

3. System hardware that is proven and reliable is available from numerous sources

4. There does not appear to be any difficulty in siting and installing the wind system hardware at Ras Ghareb.

5. There appears to be a cadre of engineers and technicians employed by the local GPC operations that can be trained to operate and maintain the windfarm.

2.0 OBJECTIVES AND BACKGROUND

2.1 Project Background

The Egyptian Electricity Authority, USAID/Cairo, and a group of U.S. consultants form a team responsible for conducting field test demonstration projects of eleven renewable energy applications in Egypt. These include the use of photovoltaic, wind and solar thermal systems for water pumping, ice making, desalination, industrial process heat and grid connected electricity. The specific objectives of the 4-year program are threefold: (1) to demonstrate the viability of renewable energy technologies in Egypt, (2) to comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision making, and (3) to establish the infrastructure necessary to ensure that renewable technologies, which have proven successful, are available for widespread use in the country.

Three tasks are planned:

(1) Field Tests - Assess some selected renewable energy systems/applications which could be suitable for commercial use in Egypt; develop detailed engineering design hardware specifications and system performance requirements; prepare RFP packages for procurring equipment; supervise the work of hardware contractors; and collect and evaluate data generated from the field tests.

(2) Supporting Analysis - Conduct technical, social, financial, economic, and market analyses of renewable systems related to the field tests. Develop a computer based Renewable Energy Information System (REIS).

(3) Training - Improve the skills of the GOE and the private sector in evaluating renewable technologies, applications, economics and markets and provide technical asistance in system design, installation, operation and maintenance.

Three of the eleven potential field test demonstration projects are wind energy system applications:

- Village Power - A number of small wind turbines (4 kWp to 25 kWp) and/or wind turbine/diesel/battery hybrid systems will be designed as stand-alone systems or interconnected with existing power distribution systems.

- Desalination - A cluster of wind turbines will be interconnected to supply power for a desalination system near the Hurghada Marine Institute on the Red Sea.

- Grid Electricity - A 250 kWp wind farm will be built near Ras Ghareb on the Red Sea. The system will operate in a fuel-saver mode for an existing power station and provide electricity to an existing transmission grid.

The proposed village power and desalination applications were selected as a result of studies and analyses of renewable energy technologies and potential applications in Egypt. These studies were conducted by U.S. government agencies and private consulting services companies in the late 1970's and early 1980's. The proposed grid electricity application at Ras Ghareb is based on (1) the significant growth in the wind system industry and in particular the success of wind farms in the U.S. and (2) the belief that the growing energy demand of settlements along the Red Sea coast, a high wind resource region of Egypt as determined from historical and current data, should consider wind energy systems as a possible renewable energy supply component in a mix of power systems for the generation of electricity.

In all developing countries, the availability and consumption of energy resources significantly impact the national economy. In most developing countries the increased use of renewable energy resources offers the potential for both stabilizing the energy resources offers the potential for stabilizing the energy resource base. The Renewable Energy Resource Field Testing Project sponsored by the USAID mission in Cairo provides an opportunity to investigate selected renewable energy options and to:

1. Comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy, planning decision-making technologies and applications;

2. Develop and sustain an Egyptian renewable energy infrastructure through establishment of data bases, information systems and organizations that effectively serve both the public and private sectors;

3. Design, install, operate and evaluate a series of renewable energy field tests which utilize commercially available technologies in applications having potential for widespread use in Egypt.

4. Conduct a formal management and technical training program, both on-the-job and specialized, and establish an intensive information dissemination program.

The primary purpose of the field tests is to provide the EEA practical working experience with renewable energy technologies and applications. This will have important implications for Egypt as the knowledge, processes and procedures resulting from the field tests are applied to further development of Egypt's renewable energy programs. The experience base resulting from the field tests is not only technical and managerial, but includes the important dimensions of institutional development, and assessments of social, economic and business factors.

Each of the 11 field tests contains seven general tasks which include site visits to obtain user requirements and site-specific operational data, the gathering and analysis of hardware/manufacturer data, and the development of conceptual designs and system performance specifications. Supporting field test activities include preparation of RFP packages, evaluation of responses, coordination and oversight of the system installation by field test project subcontractors and check-out and monitoring of system performance.

2.2 Description of Field Test #11

This field test is to demonstrate the feasibility of an array of wind turbines (wind farm) interconnected with a local electrical grid distribution system. There are seven criteria that should be considered specifically for this field test:

1. Current and future user needs
2. Size and stability of the local electrical grid
3. Evidence of a viable wind resource
4. Availability of proven and reliable commercial systems
5. Appropriate site characteristics and infrastructure for installation

6. Capability of the host organization for successful operation and maintenance of the systems
7. Potential for widespread use including social, economic and institutional aspects

The Egyptian Electricity Authority (EEA) and USAID/Cairo established that the peak capacity of the wind farm should be approximately 250 kilowatts. The proposed location for the wind farm was the village of Ras Ghareb on the Gulf of Suez across from the southern tip of the Sinai, approximately 320 kilometers from Cairo (Exhibit 2.1). The system sizing and specific location for this field test were based on a preliminary analysis of regions in Egypt where stable local grids and an historically good wind resource co-existed. These factors were investigated in detail during a site visit by personnel from the EEA and the U.S. Project Team on May 14-15, 1985.[1]

A summary of the data obtained and a discussion of conclusions and recommendations made from an analysis of these data are presented in the following sections of this document.

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[1] In attendance for the U.S. Project Team were Peter Borgo of Meridian Corporation and Seyoum Soloman and David Tyler of Louis Berger International, Inc. In attendance for the EEA were Eng. Mohamed Mitwally El-Sayed and Eng. Nagi Gowli. Discussions were held with Eng. Ibrahim Aly, the Area General Manager for the General Petroleum Company (GPC), Eng. Wahid Madbouli, a manager in the Electrical Engineering Department for GPC and various members of their staffs.

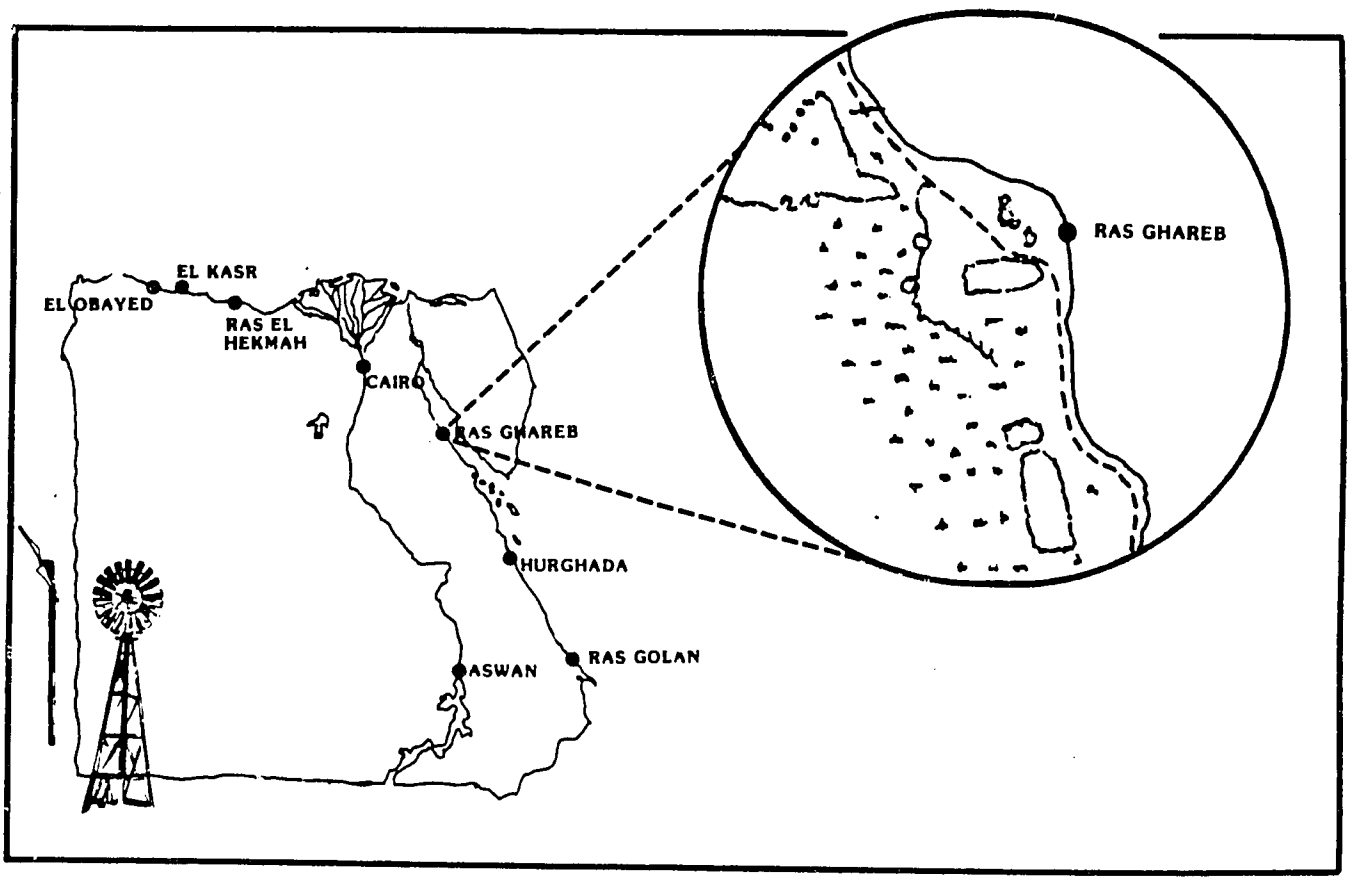

Exhibit 2.1 LOCATION OF RAS GHAREB, EGYPT

3.0 ASSESSMENT OF USER REQUIREMENTS

3.1 Electrical Power Demand

The proposed wind farm at Ras Ghareb would be interconnected with the existing electrical grid distribution system. As such, the wind farm would supply power to the grid when the wind is blowing thereby reducing the need for power from the existing power generation equipment. This mode of operation is termed a "fuel-saving" mode since the reduction in power demand from the existing generating equipment should result in a lower power demand from the gas turbines, i.e. a savings in fuel.

The village of Ras Ghareb is currently supplied with electrical power from two power plants, one operated and maintained by the General Petroleum Company (GPC) and the other by the Egyptian Electricity Authority (EEA). The GPC power plant has two 3-MW Sulzer gas turbines to meet an average 2.7 MW load demand.[2] The load consists mostly of oil drilling and pumping operations but does include about ten percent of the village power demand. Two 3-MW gas turbines are used because GPC requires a 100 percent back-up generating capacity. As of May 1985, the EEA power plant consisted of six diesel generators that supplied approximately 1.1 MW of power to supply about 90 percent of the village load. Recently a new Sulzer 5-MW gas turbine has come on-line and the diesel power plant is in the process of being shut down. A second Sulzer 5-MW gas turbine is colocated with this one, but not presently in operation. This power generation mix provides a stable, reliable source of electricity for the Ras Ghareb region.

A well maintained grid distribution system interconnects the various outlying oil fields and the village residences with the respective power plants.

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[2] Discussions with GPC and EEA engineers in May 1985.

There are two distribution systems in Ras Ghareb, a 6.6 KV line for the GPC and a 11 KV line for the EEA. Transmission cables are both overhead and undergound.

The GPC is planning for a significant growth in the next few years in the industrial load demand in the Ras Ghareb region as new oil fields are developed and interconnected with the existing grid. This growth will increase the baseline demand to more than 3 MW. In order to maintain a required 100 percent power generation back-up capacity, the GPC is installing a 5-MW Japanese gas-fired turbine. This new turbine is currently undergoing check-out tests. It may become the primary power source for GPC with the two existing 3-MW Sulzer (1976 Swiss design) turbines used for back-up.

When the new GPC 5-MW Japanese turbine comes on-line, the Ras Ghareb area will have an on-line power generating capacity of 10-MW (2x5 MW) with an 11-MW standby capacity (2x3 MW and 1x5 MW). The EEA is cognizant of the expected growth in electricity demand all along the Red Sea coast. The EEA intends to monitor the performance of this wind farm demonstration project to assess the potential for additional wind farms in the region. If wind power is a viable alternative energy source, the EEA would re-allocate existing gas turbine generators to balance regional electricity generating capacity as wind generated power comes on-line.

3.2 Load Demand Profile

The electrical demand at Ras Ghareb consists of an industrial-type load of motors and pumps to supply required power for oil drilling and oil production in the area (approximately 2.5 to 3.0 megawatts) and a typical residential-type load for power to lights and small appliances for the village itself (approximately 1.0 to 1.5 megawatts). The load demand has not been continuously monitored and recorded.

Discussions with EEA and GPC personnel in May 1985, revealed that the load demand in general is constant and continuous. Fluctuations in the residential demand are absorbed by the large baseline demand required on a 24-hour basis to run the oil production operation. Some load demand data were researched by the EEA and the GPC. They are presented in Exhibits 3.1 and 3.2.

Exhibit 3.1 is a plot of the village load demand for Ras Ghareb in the winter months. One would expect this residential-type load to be mainly lighting, which accounts for an average early morning minimum of 500 kilowatts and a mid-to-late evening peak of 1380 kilowatts. This variation in average diurnal electricity demand is consistent with most residential type loads. Summer load demand would most likely exhibit a smaller difference between maximum and minimum peak demand due to more daylight hours in the evening.

Exhibit 3.2 is an itemization of the GPC load demand for January 1985. The energy consumption data are for all of January only. GPC personnel stated that the load demand at the GPC power plant is relatively constant throughout the year. This is apparently supported for January as data indicate a relatively flat load demand profile with only a 25 percent variation between the minimum (2.25 MW) and maximum (2.8 MW) load demand.

3.3 Application Specific User Requirements

3.3.1 GPC Operational Requirements

The GPC requires a 100 percent reliability for power generation to supply the oil drilling and production operation. To achieve this level of reliability, the GPC maintains a 100 percent back-up power capacity at its power generation facility. The implications of this requirement, with regard to the addition of wind energy systems, will be studied as the performance of the wind farm is monitored. In general in the U.S., the wind power component of any

TYPICAL DAILY LOAD CURVE OF RAS GHAREB
Winter 1984

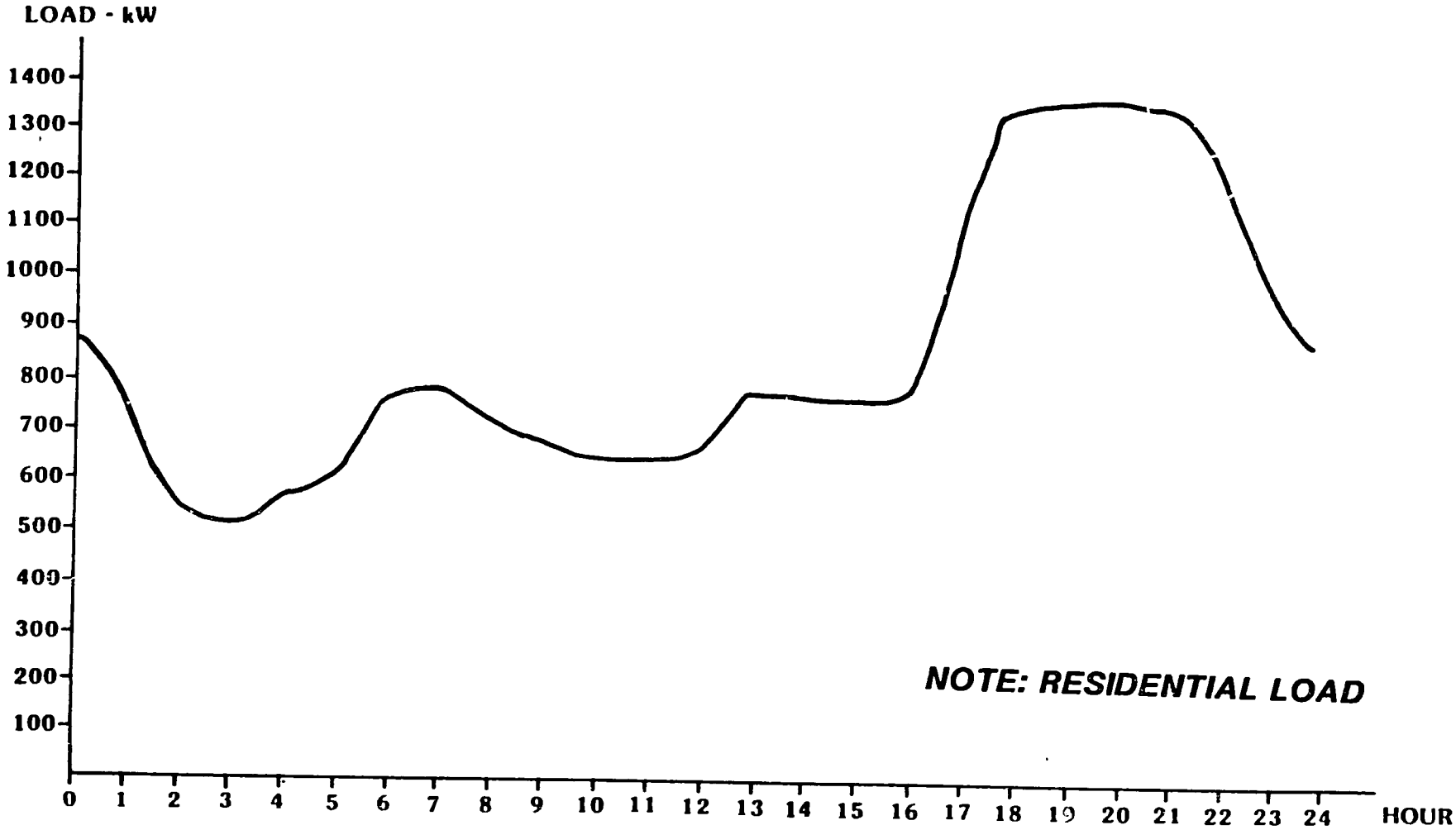

Exhibit 3.1 TYPICAL DAILY LOAD CURVE OF RAS GHAREB, WINTER 1984

SOURCE		ENERGY CONSUMED (KILOWATT-HOURS)	PERCENT OF TOTAL
Extensions of Generating Turbines		27,510	1.4
Well Pumps	Ghareb Field	357,036	18.1
	Bakr Field	192,776	9.7
	Amer Field	82,130	4.1
	Om El-Yosr	48,594	2.4
	Kariem Field	8,226	0.4
	Al-Ouien Field	47,620	2.4
Collection & Treatment Stations	Ghareb Field	48,513	2.4
	Bakr Field	27,122	1.3
	Amer Field	18,540	0.9
	Om El-Yosr Field	33,612	1.7
	Kariem Field	8,270	0.4
	El-Ouon Field	27,135	1.3
Station of Gas Compression		97,634	4.9
Potable Water Station 17° (15)		283,796	14.3
Saline Water Pumps and Oil Separators		192,154	9.8
Industrial Area		85,312	4.3
Headquarters		6,425	0.3
The employees houses and special loads belonging to the City.	The Coastal Residential Zone	6,293	0.3
	The Southern Residential Zone	35,142	1.7
	The Brick Factory Zone	39,625	2.0
	The Sulphur Factory	25,355	1.2
Ras-Bakr Camp	Potable Water & Saline Water Pumps	7,155	0.3
	Residential Area	14,310	0.7
Consumption of the Rigs		59,679	3.0
The Consumption of Shagar Field		94,783	4.8
(Unknown)		97,223	4.9
TOTAL CONSUMPTION		1,972,000	100

NOTE:

Average Load: 2.65 MW

Peak Load: 2.8 MW at 1900 hours on January 15, 1985

Minimum Load: 2.25 MW at 1500 hours on January 8, 1985

REFERENCE: General Petroleum Company (GPC)

Exhibit 3.2 ENERGY CONSUMPTION BY GPC AT RAS GHAREB JANUARY 1985

power generation mix is backed-up by another source of constant power such as fossil fueled turbine generator.

3.3.2 Wind Farm Sizing Limitation

It should be noted that due to the variablity of both electricity supply and power quality (voltage and frequency stability) from wind power generation systems, the wind power component of any grid-connected application must be small; on the order of 10 to 15 percent of the total line generation capacity at any given time.[3] This limitation will be monitored and analyzed with respect to the specific supply and demand characteristics at Ras Ghareb. In general, as a result of the uncertainty in the supply of and the variability in voltage and frequency of electricity from wind energy systems, they are not granted any capacity credit as on-line power generation systems by U.S. utilities.

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[3] Documented in various studies by the Electric Power Research Institute and independent consultants for utility companies.

4.0 ASSESSMENT OF SITE RESOURCE

4.1 Site Specific Data Base

There are two major historical sources of wind characteristics data for the Ras Ghareb area. One source consists of data gathered by Oklahoma State University for the Egyptian Wind Energy Resource Study (4 months of the data were published in November 1979). The other source is the "Harbor Station" which is a meteorological station that has been recording wind velocity and direction for at least the past five years. These data sources and the recent data being collected (Exhibit 4.4 and Section 4.2) are sufficient to support a decision on whether or not to proceed with this field test. However, based on findings of the May 1985 site visit and an earlier visit by Battelle Pacific Northwest Laboratories (PNL) in December 1984, the U.S. Project Team personnel believe that both sources of data should be used with care since the data could be influenced by the physical location of the measurement instrumentation. The wind velocity and recording sensors were located on small posts (3 or 4 meters tall) on top of 6 to 8 meter tall buildings. The buildings were located near the shoreline in the proximity of other structures which could influence the local wind velocities. In general, these measurements indicate an average wind velocity of 6.4 (4 month average) to 7.3 (annual average) meters/second (1978 Oklahoma State data and 1983 Harbor Station data respectively).

Exhibit 4.1 is a plot of the average monthly wind velocity measured at the Harbor Station at Ras Ghareb in 1983. The wind direction is almost totally from the Northwest. The annual average wind velocity is 7.3 meters/second. A winter minimum and summer maximum are clearly evident in the monthly variation in wind velocity.

Equally important with the magnitude of the wind resource at a specific site is the hourly variability of the wind. Exhibit 4.2 is the annual average

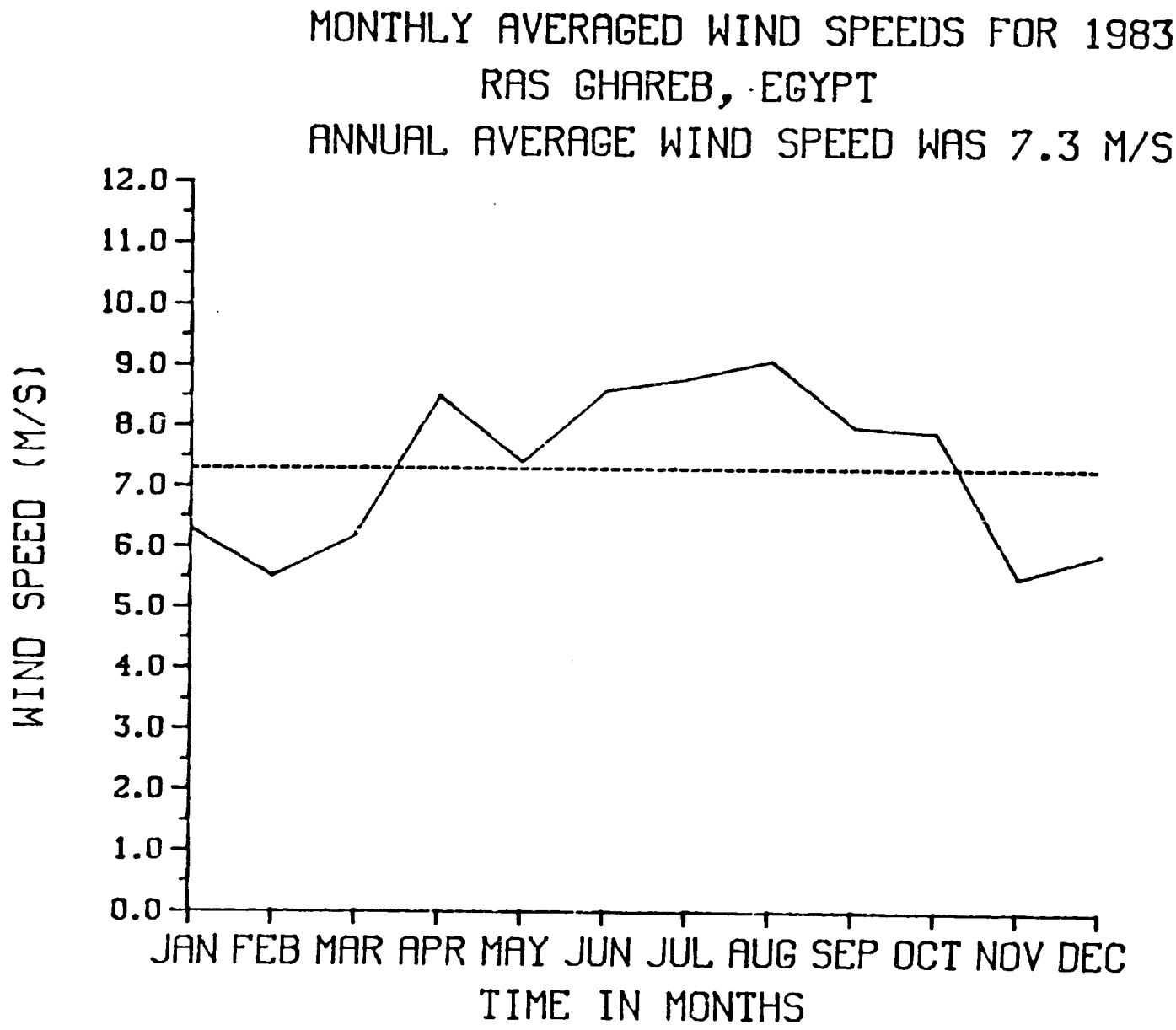

Exhibit 4.1 MONTHLY AVERAGED WIND SPEEDS FOR 1983 , HARBOR STATION

REF: BATTELLE PACIFIC NORTHWEST LAB.

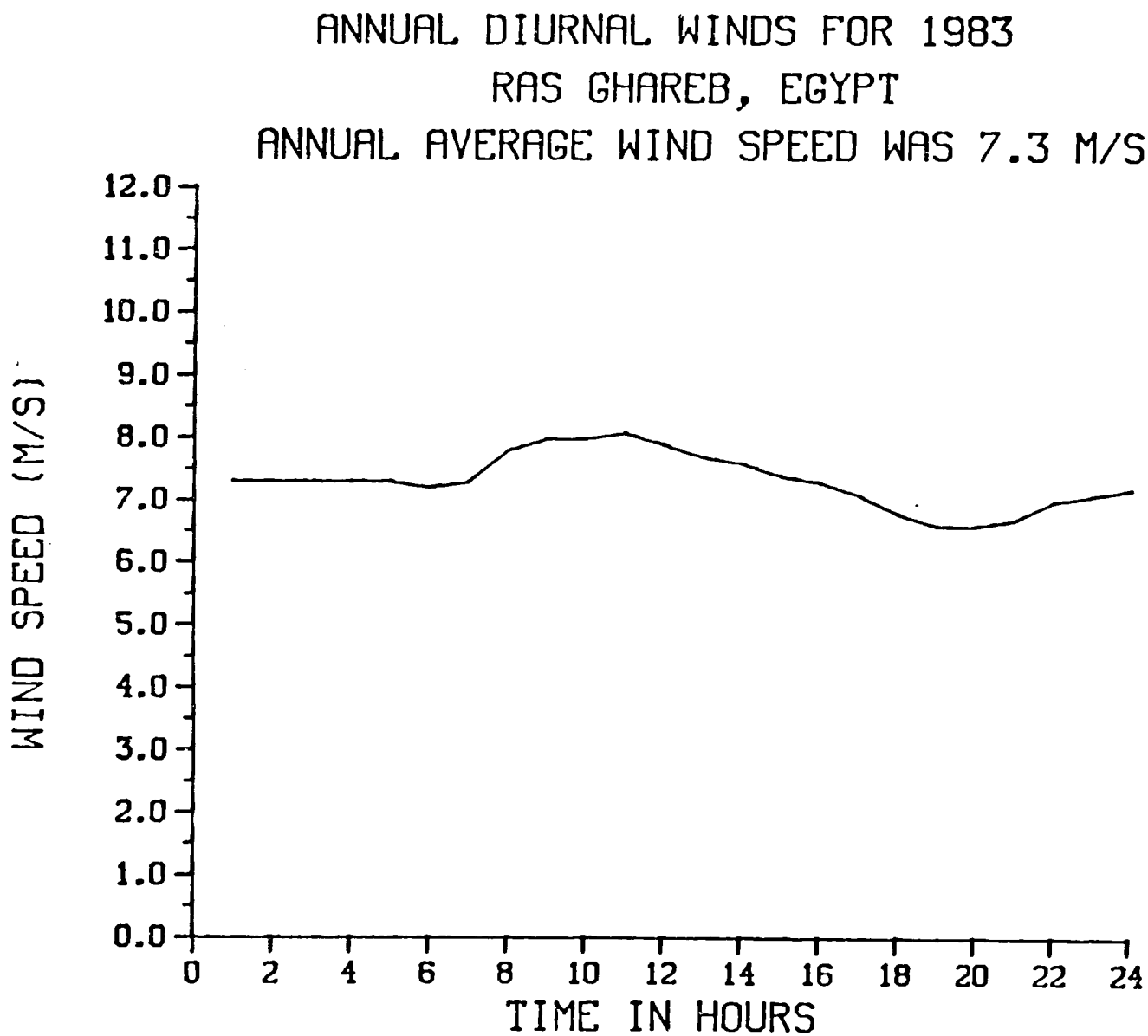

Exhibit 4.2 ANNUAL DIURNAL WINDS FOR 1983, , HARBOR STATION

REF: BATTELLE PACIFIC NORTHWEST LAB.

diurnal wind velocity measured at the Harbor Station at Ras Ghareb for 1983. The computation of an annual average diurnal value tends to smooth out actual hourly variations in the wind speed, although a slight average increase is evident throughout the morning hours and a slight average decrease occurs throughout the afternoon with a minimum occuring about sunset. Exhibit 4.3 is the diurnal wind speed cycle measured at the Harbor Station for January 1983. The greater detail in the monthly averaged data indicates significant increase in wind speed throughout the morning hours and a rather steep decline in the late afternoon. Also shown in the plot for January 1983 is the large difference between the wind speed on the maximum and minimum days of the month throughout the daytime hours.

In general, a wind resource is very site dependent, both spacially and temporally. Therefore, it is very important that wind velocity data be validated and collected as near to the actual turbine site as possible and for an extended period of time. In support of the wind energy field test, USAID/Cairo has contracted with Battelle Pacific Northwest Laboratories to conduct a wind resource assessment of Egypt. Battelle visited Ras Ghareb in December 1984 and in late March 1985 and selected a potential site for the wind farm. A twenty meter tower was installed with wind velocity and direction sensors at two levels, twenty meters and ten meters. Measurements are being recorded and will be analyzed for a period of one year. Exhibit 4.4 is a summary of the data collected and analyzed through September 1985.[4]

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[4] Interim Site Data Report, April-September 1985; January 1986, Battelle Pacific Northwest Laboratories; B. Holst, D. Renne, J. Buck.

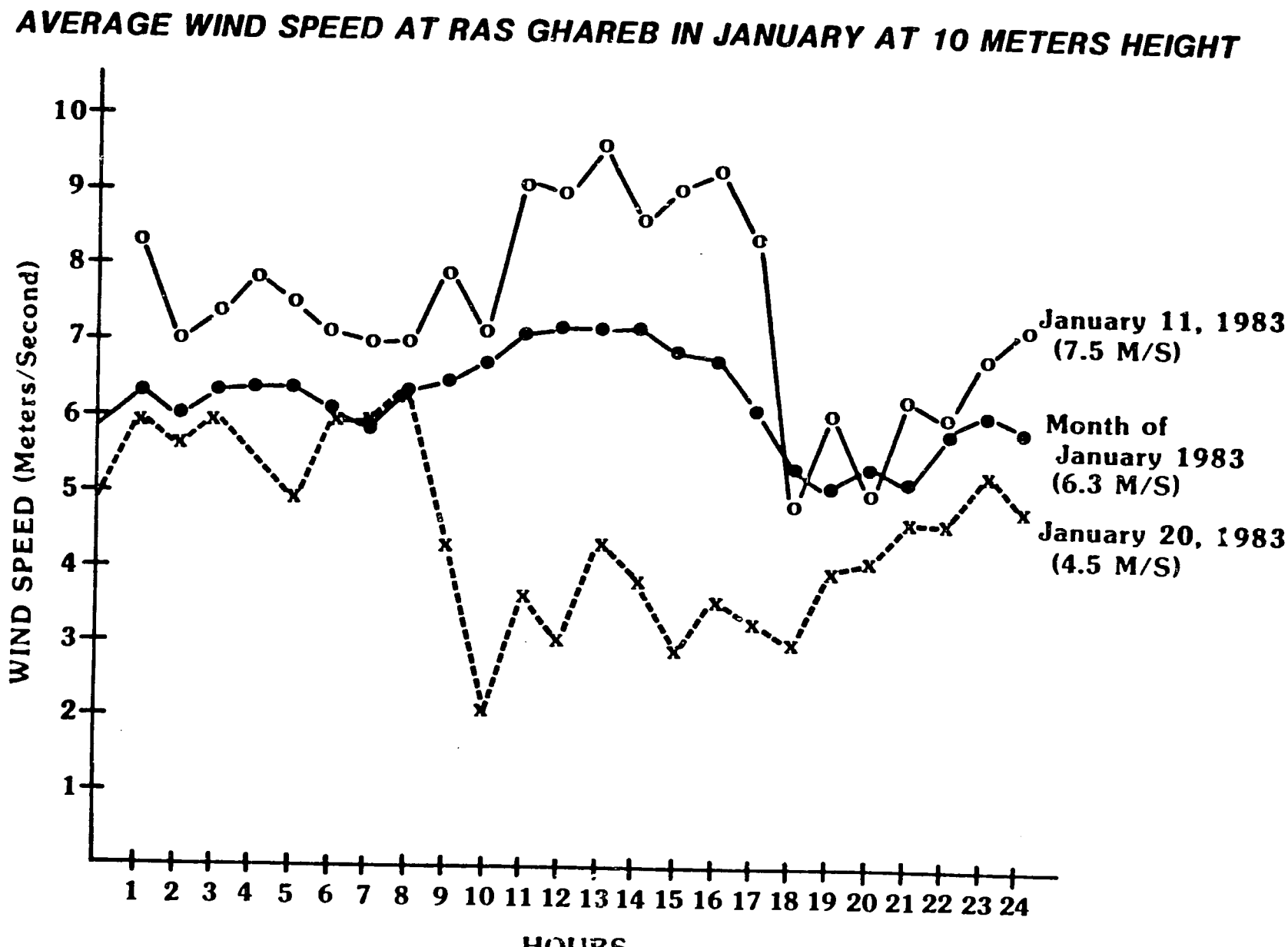

Exhibit 4.3 AVERAGE WIND SPEED AT RAS GHAREB IN JANUARY (1983) AT 10 METERS HEIGHT

Exhibit 4.4 Summary of Wind Characteristics for Ras Ghareb, April-September 1985

Month	Peak Wind (m/s)[a]	Date/Time	Average Wind Speed (m/s)	Length of Longest Lull, Ending at [b]	Date/Time	Recovery (%)
Ras Ghareb 10m						
Apr	20.3	10/11:14	7.4	11 hr.	17/6:33	100
May	19.7	12/22:40	8.3	17 hr.	7/11:20	100
Jun	19.9	26/23:32	10.0	3 hr.	2/23:40	100
Jul	18.3	28/22:19	9.6	3 hr.	21/23:08	100
Aug	19.9	25/07:47	9.7	0 hr.	-	95
Sep	19.9	11/09:36	10.0	2 hr.	22/21:42	100
Ras Ghareb 20m						
Apr	20.3	10/11:14	7.8	6 hr.	17/10:35	100
May	20.3	3/6:19	8.7	14 hr.	7/11:23	100
Jun	20.3	11/7:25	10.5	3 hr.	2/23:19	100
Jul	19.0	28/22:44	10.0	3 hr.	21/23:25	100
Aug	19.9	25/08:15	10.4	0 hr.	-	95
Sep	20.8	18/16:45	10.4	0 hr.	-	100

(a) Highest for 2-second sample.
(b) Winds less than 2.7 m/sec.

Reference: Battelle Pacific Northwest Laboratories

For the siting of wind trubines in a wind farm array, it is important to understand the effects of local terrain on flow variability across a given site. Also, a better understanding of the representativeness of long term wind characteristic data to short term site-specific data is important. Since both of these issues prevail at the Ras Ghareb site, personnel from Battelle Pacific Northwest Laboratories, Meridian Corporation and the EEA participated in a kite anemometer study to address the data uncertainties. The objectives of the study were to:

- develop information to quantify the flow variability across the proposed wind farm site so that the representativeness of the EEA/Battelle measuring station to the topography around the ridge crest could be determined.

- develop information to compare the representativeness of the Harbor Station data to the reference anemometer station at the proposed site.

Kite anemometers were flown at a 30 meter level simultaneously at the EEA/Battelle measuring station and 400 meters north and south of the station for one 20-minute measurement period. A second 20-minute measurement period was completed with the kites flown simultaneously at the EEA/Battelle measuring station, at a point 400 meters east of the station and at the Harbor Station, approximately 2 kilometers east of the station.

A variability of only 0.3 mph was detected across the ridge for the first measurement period. This variability is well within the overall uncertainty of the measurements, indicating that at the 30-meter level wind flow across the ridge was reasonably constant on this day (November 12, 1985). If a statistically significant sampling of these types of experiments were obtained with the same results, it would indicate that long-term measurements at the crest of the ridge are representative of the flow characteristics from the upwind to the downwind slopes of the ridge.

The second measurement period showed that measurements between the tower and the Harbor Station are essentially identical, indicating that if this experiment was repeated with the same results a statistically significant number of times, wind measurements at the 30-meter level at the Harbor station are representative of wind measurements at the 30-meter level at the tower. This result increases confidence that the long-term historical data collected at the Harbor Station can be applied to the wind characteristics at the proposed site.

Of course, this one study does not necessarily represent a statistically significant sampling of flow variability in the Ras Ghareb region. However, there is general agreement among the participants of this study that wind characteristics on that day were typical of what is observed in Ras Ghareb throughout much of a given day, and throughout much of the year.

4.2 Additional Data Requirements

Continuous measurement of the wind resource characteristics at Ras Ghareb is being made at the proposed wind farm site by Battelle Pacific Northwest Laboratories. A six-month data report for the period April 1985 through September 1985 was published in January 1986 (see footnote on page 19).

It is important that wind characteristic measurements be made as near as possible to the hub height of the turbines that are expected to be used in the wind farm. In general, U.S. wind turbines are installed on 24.4 meter to 30.0 meter towers. Additional data should be collected at Ras Ghareb at a 30 meter height to provide a more accurate assessment of the wind resource that the wind turbines will encounter at the specific wind farm site. In lieu of this, data from 10 meters and 20 meters can be extrapolated to 30 meters.

5.0 TECHNOLOGY REVIEW SUMMARY

Wind system hardware performance is rapidly improving after a generally poor showing by early turbine installations in the late 1970's. Measured energy production data from wind farm applications is difficult to obtain from wind farm developers, but some are indicating availability factors (the percent of time that the wind turbine is able to operate when the wind velocity is above the turbine cut-in velocity) in 1984-1985 of 95 to 97 percent with capacity factors (ratio of energy production to total estimated production at rated power output) in 1984-1985 of 8 to 35 percent as improved turbines and maintenance procedures come on-line and turbines are sited properly. System hardware components directly affecting wind farm performance are; rotor, transmission, generator and controls. Monitoring and interconnection equipment are also important subsystems. All of these components are technologically mature, of proven operation and commercially available from numerous suppliers.

A separate Technology Review document for this field test and a more general Wind Energy Technology Reference Notebook were published in January 1986 and June 1985, respectively. The Technology Review details system component technology, vendor experience and issues concerning specific applications in Egypt. The following summarizes the major findings.

Rotor - Major performance variations in turbine output generally involves rotor design. Popular materials for blade construction are wood, fiberglass and aluminum. Numerous manufacturers make rotors that are proven in operation over the past 5-years. Wooden or fiberglass blades appear to be most suitable for Ras Ghareb.

Transmission - Almost all currently operating wind farm machines contain a step-up gearbox between the rotor and the generator. Most wind turbines use helical or planetary gearboxes, with gear ratios ranging from 14:1 to 25:1. Gearbox technology is well understood and used in operational wind farms. Both helical and planetary gearboxes are appropriate for the proposed wind farm at Ras Ghareb.

Generators - Generators used in wind farm turbines are one of three standard types - synchronous, induction or direct current generators. The majority of turbines currently in operation in the U.S. wind farms use induction generators. Generators are standard systems in use

throughout the world in wind farm and other applications for the generation of electricity. Any of the three types could be used at Ras Ghareb, although induction generators seem most suitable.

Controls - Turbine controls are an important component for optimizing system performance. Turbine control prevents rotor over speed in high winds and allows turbine operation during cut-in and cut-out wind speeds. Control methods currently used are blade pitch angle control, turbine yaw control and rotor braking. Many different control systems exist from numerous manufacturers. Rotor braking appears to be the simplest and most practical for application at Ras Ghareb.

Monitoring - Wind farm monitoring systems are essential for providing information on such critical wind farm performance variables as output, energy production, availability, machine status, and wind speed and direction. Systems include a data collection unit to collect information from one or more turbines and a computer to process the data. A number of types are commercially available.

Interconnection - Equipment required for safe connection of a wind farm to a utility grid includes transformers, switchgear, relays and suppressors. This equipment is standard in the electric utility industry. What distinguishes the application of this equipment in grid-connected wind farms is the fact that the power flow is extremely transient. Some of the major concerns with such applications are: Safety for operating and service personnel, and equipment; transient and dynamic stability behavior; the effect of power variability on system dispatch and unit commitment; optimum bus configuration and voltages for array interconnection; and array control. Ras Ghareb appears to have no unusual interconnection problems.

Requirements for utility interconnect are resulting in significant hardware development of power conditioning equipment. Stringent requirements for phase control, voltage regulation and safety have resulted in improvements in inverters, generators and control systems.

The U.S. wind industry is still in a stabilizing period after an extremely rapid growth in 1982, 1983 and 1984. There are currently approximately 30 U.S. manufacturers producing wind turbines. Of these, about fifteen sold a significant number of machines in 1984 and 1985. Most of the successful manufacturers sell small (less than 100 kW, rated capacity) horizontal axis machines, although a trend appears to be developing toward larger machines sizes. In 1984, the average size of installed turbines on wind farms in the U.S. was 81 kW; in 1985 it increased to 90 kW. Several companies are

designing and beginning to market intermediate-sized (200-500 kW) machines. Two U.S. manufacturers, are currently manufacturing vertical axis (Darrieus) machines in the 100-200 kW range.

The growth of wind farms is the most encouraging indicator of industry progress. At least 50 developers have installed wind farms in the U.S. to sell electricity to more than 15 utilities. The majority of wind farm applications are in California, where approximately 8800 machines totalling almost 1,000 megawatts of capacity are currently installed. This is an increase from about 1700 machines and 70 megawatts at the end of 1982. As a result of the industry's growing experience, the cost of energy production from wind farms has declined from about U.S. $0.25/kWh in 1977 to about U.S. $0.10/kWh to $0.12/kWh in 1985.

There is no question that the rapid growth of the wind industry resulted from the tax incentive available in the United States since 1978. These tax advantages expired on December 31, 1985. The continued success of the industry, as measured both by the number of companies and by the growing sales of machines, will soon be measured by how well the industry survives the transition to an era when most of the favorable tax investment opportunities of the early to mid-1980's are gone. A second challenge is posed by foreign competition, particularly from northern Europe. Nearly half of the turbines in the U.S. by the end of 1985 will be of foreign manufacture. A third challenge is the continuing weakness in world oil prices and the consequent stabilization of electric rates and avoided costs.

The net effect of these changes is that a new, more difficult time awaits the industry. In the future, the industry must show wind machine performance and economics to offset the loss of tax advantages, oil-price-driven market share, and foreign competition. Accordingly, the current focus of the industry is to make machines that meet the necessary performance and economic standards and to obtain a significant share of a developing world market.

6.0 PRELIMINARY CONCEPTUAL DESIGN

6.1 Wind Farm Sizing and System Configuration

A wind farm sizing limitation (Section 3.3.2) suggests a maximum wind farm size of approximately 400 kilowatts for the current load demand at Ras Ghareb. A more conservative size would be 10 percent of the average expected minimum power demand or approximately 250-275 kilowatts peak. This limitation will be investigated for the Ras Ghareb application by careful monitoring of the voltage and frequency stability of the grid during this field test as wind generated power is introduced.

Using the singular measure of peak kilowatts of wind generated power is not always sufficient to determine the effect of a wind farm on a particular grid distribution system. An equally important parameter is the level of energy in kilowatt-hours that is introduced into the distribution system at any given time. For example, a 10 percent wind energy component of a power generation mix (based on peak kilowatts) can have a large impact on total energy produced (in kilowatt-hours) during periods when there is a low load demand and the wind velocity is high. Consideration must be given to the level and variability of a relatively continuous baseline load demand for a specific application when the wind system component is being sized.

In August 1985, engineers from Meridian Corporation, the EEA and the GPC conducted a joint analysis to investigate the desired size and estimated energy production of a wind farm at Ras Ghareb that would satisfy the objectives of this field test.[5] This analysis was completed to provide support for a decision on whether or not to proceed with this field test as well as to provide specifications

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[5] Estimated Power Production From a Wind Farm at Ras Ghareb, Egypt, August 1985, Egyptian Electricity Authority, General Petroleum Co. and Meridian Corp., M. El-Sayed, F. Nagaty and R. Russo.

for evaluation of wind farm design and performance estimates submittted by bidding contractors in response to a tender document.

The study methodology was to evaluate the performance of wind turbines manufactured by eight different U.S. companies in the wind resource measured at the Harbor Station at Ras Ghareb in 1983. The evaluation was performed using a wind system performance computer model developed by Meridian Corporation.[6] A comparison was made between the energy production data for a range of wind velocities as specified by the turbine manufacturer and as computed by the system model using operating characteristics of the respective wind turbine, i.e., cut-in, cut-out, and rated wind velocity and rated power. Manufacturer's data from the published turbine power curves were used. Wind speed frequency distribution was assumed to be a Rayleigh distribution.

Eight wind turbines (seven horizontal axis and one vertical axis) were evaluated. Rated power output of the turbines ranged from 10 kilowatts at a rated wind velocity of 12.1 meters/second to 200 kilowatts at a rated wind velocity of 16.7 meters/second. Rotor diameters ranged from 7 meters to 18.1 meters respectively. The eight turbines are representative of American manufactured turbines being used in California wind farms and turbines that are being used in stand-alone rural electric and irrigation applications throughout the United States. Pertinent descriptive hardware system specifications and operational parameters for these turbines are shown in Exhibit 6.1.

Turbine energy production was computed using the Wind Energy System Performance Model for wind speeds of up to 20 meters per second for increments of one meter per second. This was done to compare model results with published

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6 "Wind Energy System Performance Model-Users Manual," March 1983, Meridian Corporation.

TURBINE MODEL	ROTOR DIAMETER (METERS)	NOMINAL TOWER (METERS)	RATED POWER (KILOWATTS)	CUT-IN VELOCITY (M/SEC)	CUT-OUT VELOCITY (M/SEC)	RATED VELOCITY (M/SEC)	SURVIVAL VELOCITY (M/SEC)
BWC EXCEL-10	7.0	18.3-36.6	10	3.1	NONE	12.1	54
JACOBS 29/20	8.8	24.4-36.6	20	3.6	NONE	12.1	54
CARTER SYSTEMS MODEL 25	9.8	18.3-24.4	25	3.4	NONE	11.6	55.9
ENERTECH 44/50	13.4	24.4	50	3.8	22.3	14.8	54
STORM MASTER MODEL 12, SERIES 6	12.0	19.5-24.4	60	5.0	25.0	17.0	70
ESI-54S	16.5	24.4	80	3.1	NONE	12.4	44.7
NORTH WIND	17.0	21.3	100	3.5	37.0	13.6	55.0
VAWTPOWER 185-II	18.1 (Vertical Axis)	30.4 (Overall Height)	200	5.4	22.4	16.7	NONE SPECIFIED

EXHIBIT 6.1 WIND TURBINE SPECIFICATIONS

performance data from the manufacturer. A Rayleigh wind speed frequency distribution was assumed together with specific turbine hardware and operating characteristics as given in Exhibit 6.1 An example of the results of these comparisons between the model simulations and the manufacturer's published performance data is shown in Exhibit 6.2. The results indicate that the manufacturer's published data compare favorably with the model output.

The wind speed frequency distribution at Ras Ghareb is important in estimating wind turbine performance since the Wind Energy System Performance Model assumes a Rayleigh distribution for all turbine performance simulations. Exhibit 6.3 is a plot of the actual measured annual percent-of-time wind data at the Harbor Station in 1983 (EEA data) and a Rayleigh distribution based on the measured 7.3 meter per second annual average wind speed. It is apparent that the wind speed in 1983 was not Rayleigh distributed at the Harbor Station.

A comparison was made between turbine energy production using the actual wind frequency distribution and that determined by the model using an assumed Rayleigh distribution. Results indicated that the model computes a lower energy production than that calculated from the actual distribution for those months where the monthly average wind speed is higher than the annual average and a higher energy production when the monthly wind speed average is below the annual average. For the annual wind speed summary for 1983, however, the energy production estimates with the actual wind speed distribution are within 10 percent of those obtained assuming a Rayleigh distribution.

Results of the computer simulations to estimate the power production of the eight turbines sited at Ras Ghareb are given in Exhibit 6.4. A reasonable value for the minimum annual energy production from a wind farm of approximately 250 kilowatts peak power is approximately 625,000 kilowatt-hours per year with a 90 percent turbine availability. Each of the eight representative turbines can meet this power production level with turbines of a total rated power that is

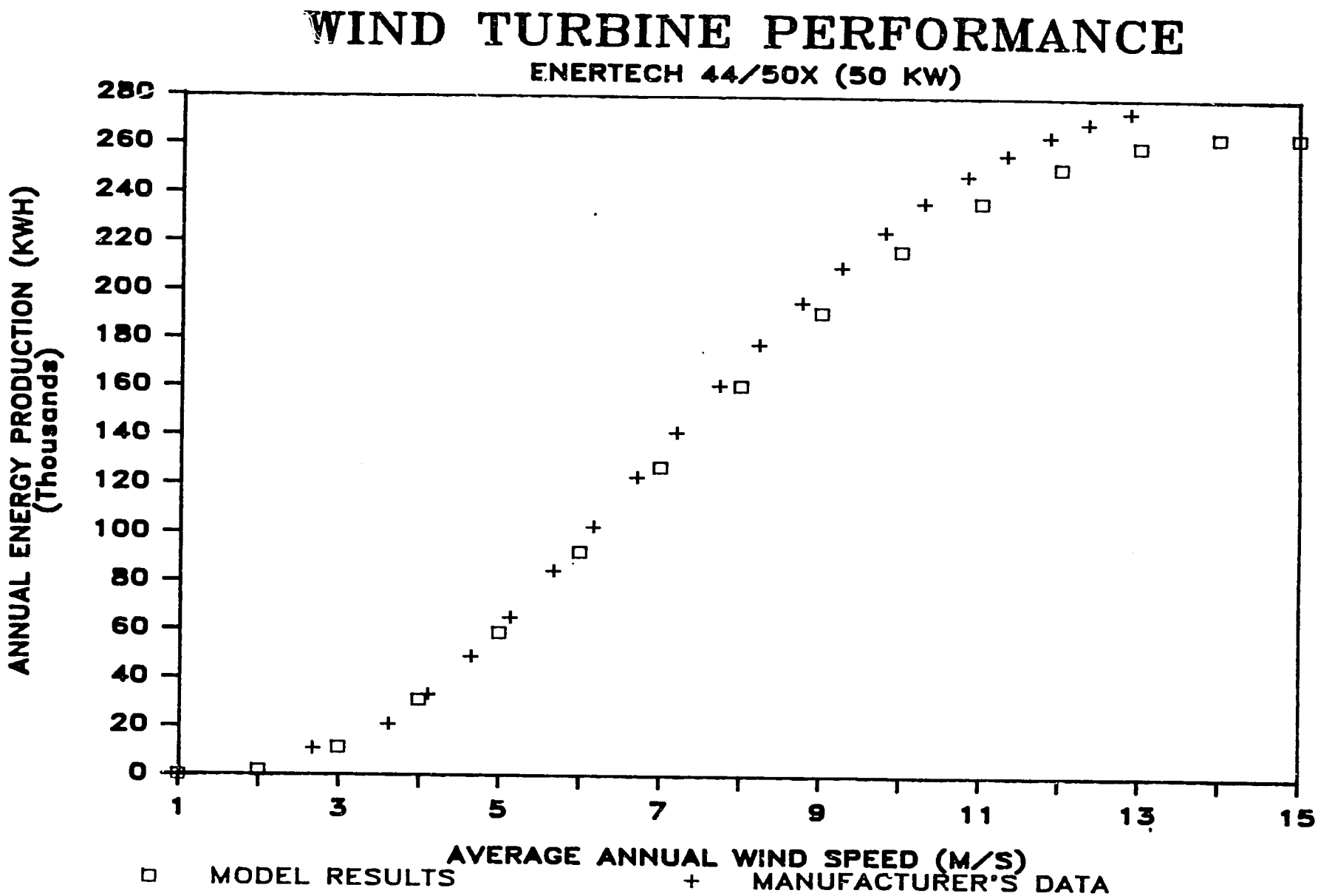

Exhibit 6.2 WIND TURBINE PERFORMANCE FOR AN ENERTECH 44/50X

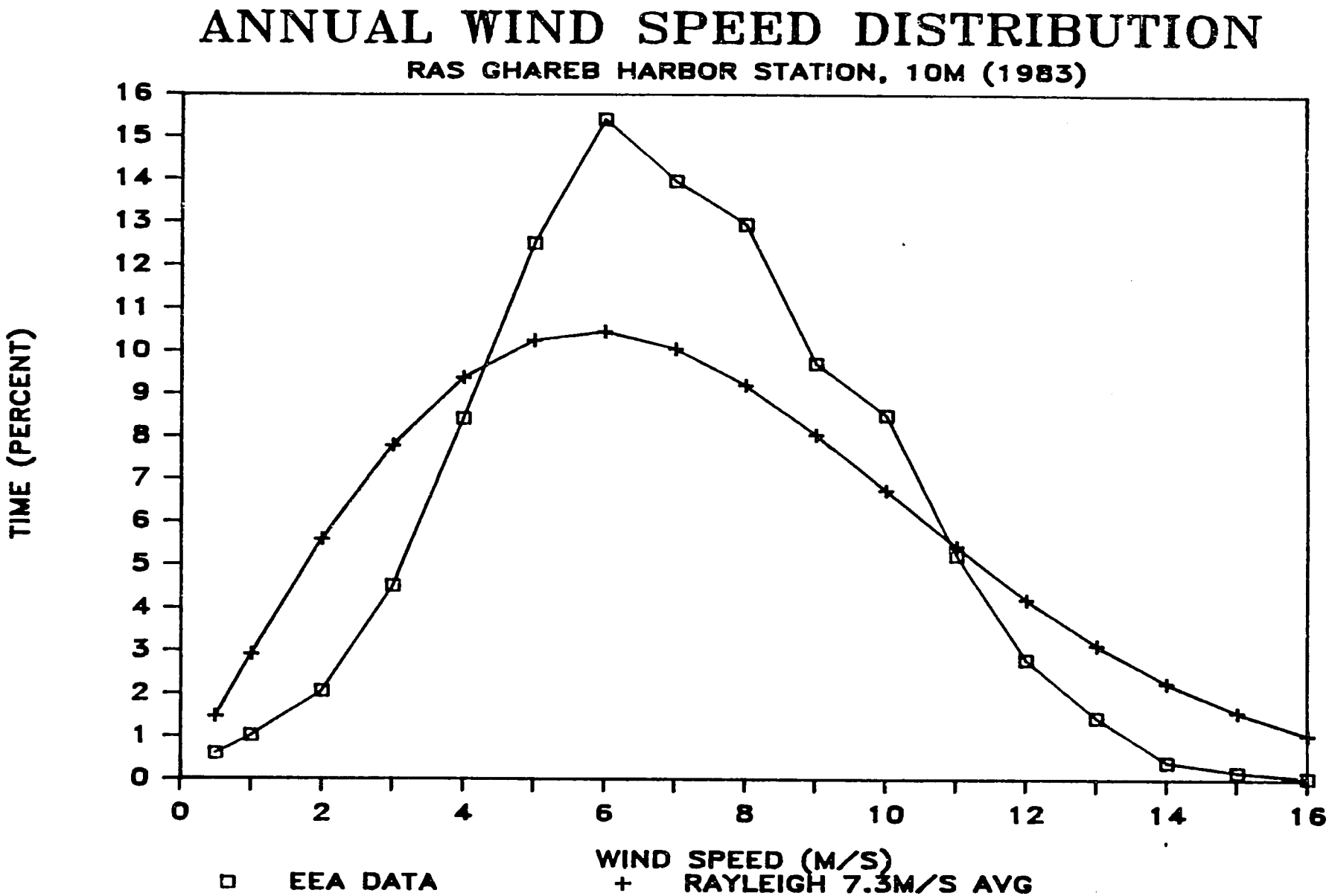

Exhibit 6.3 ANNUAL WIND SPEED DISTRIBUTION, HARBOR STATION, RAS GHAREB, 1983

TURBINE	TOWER HT. (meters)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BWC EXCEL-10	36.6	2469	1699	2409	3450	2130	3461	3644	3689	3270	3348	1813	2221
JACOBS 29/20	24.4	3831	2527	3729	6332	5253	6372	6863	7079	5733	5833	2696	3385
CARTER MODEL 25	18.5	5062	3456	4945	7503	6567	7536	8009	8173	6982	7131	3688	4544
ENERTECH 44/50	24.4	10325	6930	10066	16443	13862	16539	17757	18272	14999	15277	7394	9191
STORM MASTER	19.5	7217	4510	6991	13403	10525	13512	14724	15347	11817	11976	4807	6242
ESI-54S	24.4	13055	8404	12687	21954	18128	22094	23818	24587	19838	20177	8961	11443
NORTH WIND 100 kW	21.3	14878	9044	14385	27892	21967	28114	30626	31883	24646	24984	9636	12743
VAWTPOWER 185-II	30.4	26502	16395	25665	48136	38406	48496	52654	54654	42801	43427	17472	22868

NOTE:
- o 1983 Harbor Station Wind Data
- o Rayleigh Frequency Distribution Assumed
- o Nominal Tower Height for Each Turbine (Manufacturer Specified)
- o Manufacturer Data for Turbine Power Curve
- o 100% Turbine Availability

Exhibit 6.4 ESTIMATED ANNUAL POWER PRODUCTION AT RAS GHAREB IN KILOWATT-HOURS

TURBINE	TOTAL (kWh)	TOTAL (kWh/kWr)	TOTAL (kWh/m^2)
BWC EXCEL-10	34,596	3460	899
JACOBS 29/20	59,633	2981	980
CARTER MODEL 25	73,604	2892	976
ENERTECH 44/50	157,054	3141	1114
STORM MASTER	121,082	2018	1071
ESI-54[illegible]	205,144	2564	959
NORTH WIND 100 kW	250,796	2508	1105
VAWTPOWER 185-II	437,477	2187	1492

NOTE:
- o 1983 Harbor Station Wind Data
- o Rayleigh Frequency Distribution Assumed
- o Nominal Tower Height for Each Turbine (Manufacturer Specified)
- o Manufacturer Data for Turbine Power Curve
- o 100% Turbine Availability

Exhibit 6.4 ESTIMATED ANNUAL POWER PRODUCTION AT RAS GHAREB IN KILOWATT-HOURS (CONTINUED)

well below the assumed 400 kilowatt maximum value for the wind farm. Four of the turbines can generate 640,000 kWh annually with a wind farm size of about 250 kW.

In summary the results of this conceptual design study to size the wind farm and to provide specifications for a tender document and a system acceptance test are:

- Maximum size of approximately 400 kilowatts rated power
- Minimum size of approximately 250 kilowatts rated power
- Turbine availability of 90 percent
- Minimum annual energy production of 625,000 kilowatt-hours

It should be noted that the specification for a minimum annual energy production should be revised for the release of a statement-of-work in a tender document based on an updated wind resource assessment provided by Battelle Pacific Northwest Laboratories (see Section 4.2).

U.S. wind turbine technology is relatively mature (see Section 5.) and turbines are available in many sizes from a few hundred watts to multi-megawatts.[7] In California, the average installed turbine size has been steadily increasing to 81 kilowatts peak at the end of 1984.[8] Considering this trend, the results of the Meridian/EEA/GPC conceptual design sizing study and the overall REFT Project objectives, wind farm field test demonstration for Egypt should be an installation of a reasonable number of interconnected and commonly controlled turbines connected to an existing electrical grid. The selection of between 5 and 15 moderately sized wind turbines each between (20 and 65 kilowatts peak) is recommended.

6.2 Civil Works/Site Preparation Requirements

The proposed wind farm site at Ras Ghareb is located along a ridge line

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7 Wind Energy Technology Reference Notebook, Meridian Corporation for the Egyptian Electricity Authority and the USAID Mission, Cairo, June 1985.

8 Technology Review, FT #11: Wind Farm at Ras Ghareb, Meridian Corporation, January 1986.

at an elevation of approximately 42 meters above sea level. The site, in a treeless coastal desert region, is unobstructed to the prevailing northwest winds. There ae no natural obstructions or man-made structures that will influence the flow of the wind across the wind farm. The high-voltage transmission line interconnect point is approximately 200 meters west of the proposed wind farm site.

Some civil work is required to level the site. An access road capable of transporting heavy equipment (turbines, towers, cement trucks, cranes) will also be required. A soil analysis should be completed as soon as possible to provide data on soil strength so that an assessment on the specifications and cost of the road can be made. Also soil strength data will be required for the preparation of the statement-of-work so that bidding contractors can accurately cost the turbine/tower foundations. A building(s) to house the wind farm control systems, performance monitoring instrumentation and some number of spare parts/maintenance equipment will also be required.

6.3 Infrastructure Considerations

A key factor in the success of a wind farm field test demonstration is the ability of the host organization to operate and maintain the system. This is especially critical for this field test of the first operating wind farm in Egypt and the first electricity generating wind trubines along the Red Sea coast. The GPC engineers and technicians have constructed numerous oil drilling rigs. They competently and efficiently maintain large rotating machinery, both megawatt size gas turbines and numerous diesel engines. They also have installed and continue to maintain their own electrical transmission grid, including transformers and switch gear. With appropriate training (which is provided under a separate task of this field test project and will be a part of the responsibility of the wind farm installing contractor), GPC personnel could operate and maintain a wind farm.

7.0 ADDITIONAL CONSIDERATIONS

7.1 Projected Wind System Technical and Cost Goals

Exhibits 7.1 and 7.2 present projected cost goals for wind energy systems in the United States. These projections were made by the U.S. Department of Energy (DOE) in the Federal Wind Energy Program 5-year Research Plan (1985-1990) dated October 1984.

It is interesting to compare these projected goals with the energy production estimates resulting from the Meridian/EEA/GPC conceptual design sizing study (Section 6.1). The DOE goals were established using turbine energy production estimates for an annual wind speed of 6.3 meters per second at a tower height of 10 meters. Exhibit 6.2 can be used to estimate the energy production for an Enertech 44/50x for an annual wind speed of 6.3 meters per second.

For the Enertech 44/50x, an annual energy production (90% availability) of 97,188 kilowatt-hours divided by 141 square meters (area swept by the rotor) yields a "current technology" of 689 kWh/m^2, which compares favorably with the DOE range of 300 to 800 kWh/m^2. This type of analysis can be used to evaluate turbine performance data supplied by the bidding contractors in response to the tender document for this field test.

7.2 Social and Institutional Aspects

Social and Institutional aspects of this field test are being addressed under Task 2.1, Economic/Market Assessment. Results of these investigations will be submitted under separate cover. A review of all relevant agreements between USAID, the EEA and all participating entities should be undertaken to insure the decision to proceed or not with this field test is based on an accurate appraisal of the existing situation. This includes concurrence by all parties that the field test as specified in this Application Review is acceptable, that all responsibilities of participants are clearly specified and understood, and that required site preparation and civil works can be completed in a timely fashion.

WIND TECHNOLOGY STATUS AND TECHNICAL GOALS (1984 DOLLARS)

	CURRENT TECHNOLOGY[A]	TECHNICAL GOALS
ANNUAL ENERGY PRODUCTION AND INSTALLED COST RANGES (PER SQUARE METER OF SWEPT ROTOR AREA)	300 kWh/m^2 AT \$600/m^2 TO 800 kWh/m^2 AT \$1100/m^2	900 kWh/m^2 AT \$450/m^2 TO 1500 kWh/m^2 AT \$750/m^2
ANNUAL OPERATION AND MAINTENANCE COST	2¢/kWh	0.5¢/kWh
AVAILABILITY	WITH 85% TO 95%	WITH > 95%
LIFE-EXPECTANCY		
• MAJOR FATIGUE-RELATED COMPONENTS	5 YEARS	30 YEARS
• BALANCE OF SYSTEM	30 YEARS	30 YEARS
30-YEAR LEVELIZED COST OF ELECTRICITY	10¢ TO 15¢/kWh	4¢/kWh

[A] ENERGY PRODUCTION FOR CURRENT MACHINES WAS ESTIMATED FOR AN ANNUAL AVERAGE WIND SPEED OF 6.3 M/S (14 MPH), AT A HEIGHT OF 10 METERS, TO ALLOW COMPARISON WITH THE LONG-TERM GOALS. ELECTRICITY COST ESTIMATES EXCLUDE SOLAR TAX CREDITS.

Exhibit 7.1 WIND TECHNOLOGY STATUS AND TECHNICAL GOALS (1984) – TABLE (1984 DOLLARS)

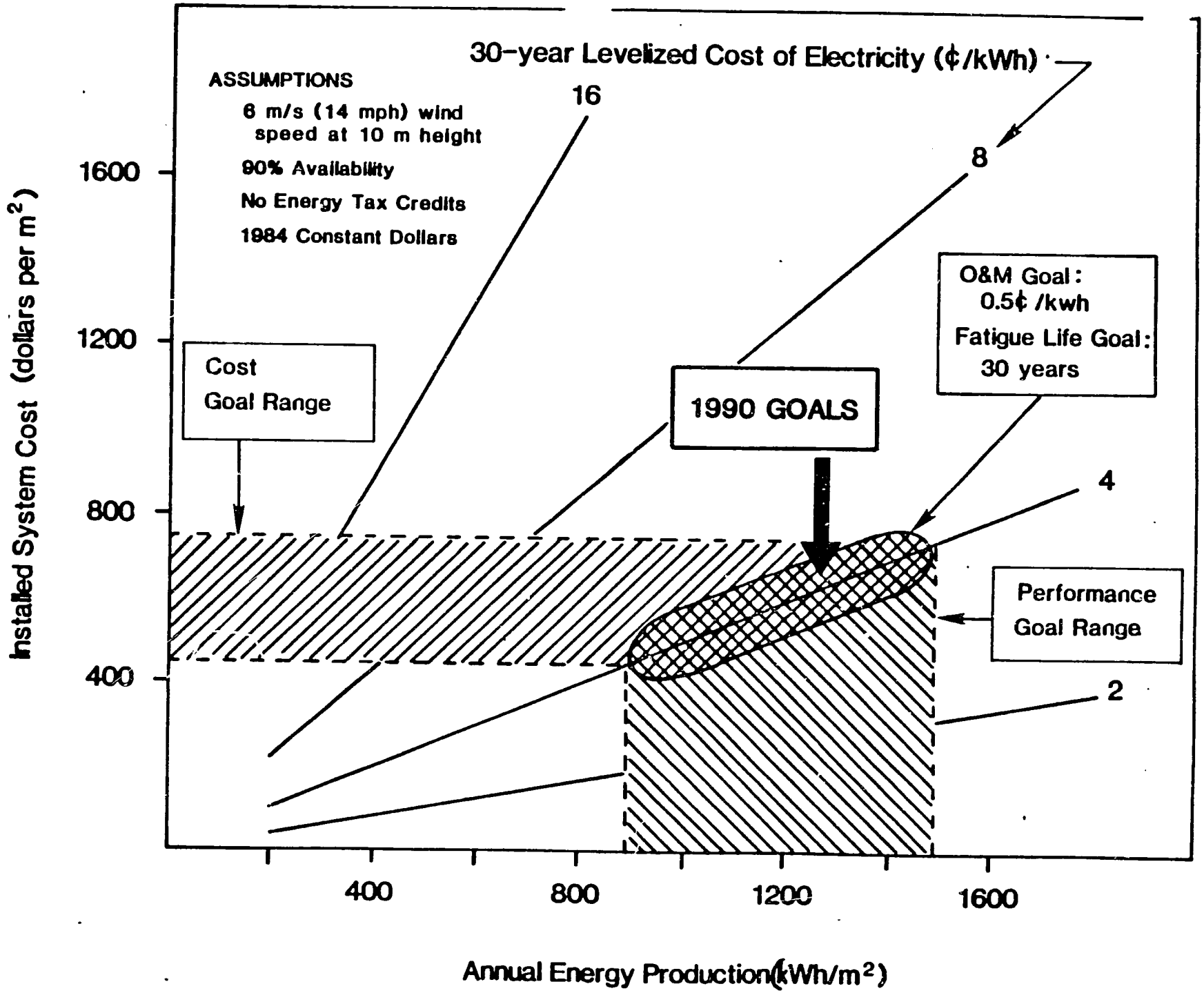

Exhibit 7.2 WIND TECHNOLOGY STATUS AND TECHNICAL GOALS – GRAPH (1984 DOLLARS)

8.0 CONCLUSIONS AND RECOMMENDATION

The findings in this Application Review support a strong recommendation that a grid-connected windfarm of approximately 250 kilowatts should be designed, purchased and installed at Ras Ghareb. All the necessary criteria for a successful wind farm installation appear to be satisfied at the Ras Ghareb location as follows:

- The current and future electricity needs of the Ras Ghareb region are supplied by a stable grid that should be able to accept a 250 kilowatt wind farm.
- The wind resource is excellent
- System hardware that is proven and reliable is available from numerous sources
- There does not appear to be any difficulty in siting and installing the wind system hardware at Ras Ghareb.
- There appears to be a cadre of engineers and technicians employed by the local GPC operations that can be trained to operate and maintain the windfarm.

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