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Office of Energy and Infrastructure
Bureau for Research and Development
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WIND-ELECTRIC WATER PUMPING IN NAIMA, MOROCCO: A CASE STUDY

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FORWARD

The Office of Energy is pleased to present this case study of a renewable energy project funded by the United States Agency for International Development (USAID). The study details a project developed in cooperation with the Government of Morocco and U.S.A.I.D./Rabat to install and commission a wind-electric water pumping system for the supply of potable water to the commune of Naima in eastern Morocco. The Office of Energy believes that the perspective of the U.S. company which supplied and installed the pumping system will provide important insights for institutions involved in funding similar projects and in fostering the transfer of renewable energy technologies to developing countries.

This report has two objectives: 1) to describe a renewable energy technology which can provide potable water on a cost-effective, economically sustainable, and environmentally sound basis; and 2) to provide officials considering the application of renewable energy technologies with pragmatic lessons learned which illustrate the importance of the institutional framework in effective project implementation and the long-term sustainability.

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DISCLAIMER

The statements, opinions, comments, and data presented and expressed in this report are the sole responsibility of the author and Bergey Windpower Co., Inc. and in no way are attributed to International Development and Energy Associates, Inc. or the United States Agency for International Development.

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ACRONYMS

BWC	Bergey Windpower Co., Inc
CDER	Centre de Developpement des Energies Renouvelables
DOE	United States Department of Energy
DPA	Delegation Provinciale d'Agriculture
ERDA	Energy Research and Development Administration
IDEA	International Development and Energy Associates, Inc.
MAE	Maroc Aero Energies
MREDP	Morocco Renewable Energy Development Project
O&M	Operations and Maintenance
RTI	Research Triangle Institute
RFP	Request for Proposal
PASA	Participating Agency Service Agreement
PV	Photovoltaic
SERI	Solar Energy Research Institute [U.S. DOE, now National Renewable Energy Laboratory, (NREL)]
TA	Technical Assistance
USAID	United States Agency of International Development
USDA	United States Department of Agriculture

I) INTRODUCTION

CDER

The Centre de Developpement des Energies Renouvelables (CDER) was established in 1982 under funding from the Moroccan Ministere de L'Energie et des Mines and the U.S. Agency for International Development (USAID). The mission of CDER is to serve as a center of study and research in support of the promotion, development, commercialization and utilization of renewable energy. For USAID, CDER was to serve as an implementing agency with centralized responsibility for promoting the adoption of renewable energy technologies throughout Morocco. Through the seven year (1982-1989) $9.7 m Morocco Renewable Energy Development Project (MREDP), USAID was a major factor in the establishment and operational support of CDER.

CDER has a staff of approximately sixty people and is located in Marrakech. The MREDP also provided for the funding of a U.S. technical assistance (TA) contractor with expertise in renewable energy to be resident with CDER . This contract was originally held by Research Triangle Institute (RTI) and later by International Development and Energy Associates (IDEA). The size of the TA contractor staff in Morocco averaged approximately five people.

Naima Wind Project

The Naima Wind Project was one of a series of USAID funded CDER demonstration projects aimed at introducing small-scale rural-oriented renewable energy technologies. Projects were conducted with solar thermal, photovoltaic, biomass, micro-hydro and wind power technologies. Previous MREDP wind power projects involved a U.S. supplied 12 kW battery-charging wind generator for village power and pumping, a technology-transfer program for a Dutch 5m diameter mechanical water pumper, and a training program in the rehabilitation of old mechanical wind pumps (many of which are of U.S. origin).

The Naima Wind Project is an enhancement of an existing diesel-powered water supply system serving four water points over a 120 square kilometer area in the Naima Commune of Oujda Province. The site i located in northeast Morocco close to the Algerian border and approximately 60 km south of the Mediterranean Sea. The wind systems and related equipment were supplied under contract by Bergey Windpower Co. (BWC) of Norman, Oklahoma following a competitive procurement.

The Naima Wind Project is believed to have had three objectives. The first was to demonstrate a more sustainable alternative to diesel pumps for community water supply; one in which equipment utilization, by virtue of lower O&M costs, was less dependent on the user's financial resources. The second was to encourage the commercialization of a wind pump system architecture (direct wind-electric water pumping) that offered the promise of lower costs and greater reliability than conventional battery-charging system and mechanical architectures. [This objective was championed by the USAID/CDER TA contractor on the project and its implications may not have been fully appreciated by CDER or USAID.] The final objective of the project, and one that was never officially mentioned, was to put a significant demonstration project in the home province of the Minister of Energy, whose agency was responsible for CDER.

In the Naima project, two BWC 10 kW wind turbines power off-the-shelf multistage submersible pumps piped in parallel to the existing diesel powered potable water supply network. The existing diesel systems were unsatisfactory because the Naima Commune, which is responsible for operations and maintenance, could only afford to operate the pumps a few hours a day. Also, one of the diesel pumps, at Dar El Hamra, had been shutdown for repairs for over two years, causing the people near Rmilat to carry water 2 to 5 km. The Naima water supply network serves both rural families and their livestock.

The water source for the network is a spring at Ain Tolba. At Ain Tolba a wind turbine drives a five-stage pump installed in a newly constructed 40 m3 sump and pumps water 750 m against a 25 m (at the average flow rate) total dynamic head to a 200m3 tank. Because the terrain around the Ain Tolba sump is too rugged to install a turbine tower, the turbine is actually installed some 220m from its pump. Water flows by gravity from the Ain Tolba tank 6-9 km to tanks at Hachleff and Dar El Hamra. At Dar El

Hamra the second wind turbine and a twenty-six stage pump pumps water from a 100 m3 tank 4.5 km against a 130m (at an average flow rate) total dynamic head to a reservoir at Rmilat. At both pumping sites the head turned out to be substantially higher than specified in the project RFP. The historical average wind speed for the area is 4.1 m/s, but the systems were designed for the worst case month of October, at 3.6 m/s. This is a relatively poor wind resource. A more complete description of the Naima project is contained in Appendix 1. Site pictures from Ain Tolba and Dar El Hamra are provided in Appendix 2.

The systems were installed in April and June of 1989, but were not made properly operational until February of 1990. Predicted annual water delivery for the two systems, corrected for actual site conditions, is approximately 34,000 m^3. This is over three times the calculated delivery from the diesel systems (assuming the Dar El Hamra diesel to be operational, which it now is), providing a far better utilization of the spring flow at Ain Tolba. The local users say that they are very pleased with the extra water provided by the new systems.

The contract to BWC for the Naima project was for $120,000, including a number of one-time expenses and some follow-up support. The replication cost for the 20 kW project, including all civil works, but excluding special instrumentation, would be approximately $60,000 in 1990 dollars. The expected operations and maintenance cost, including the cost of back-up diesel pumping, is approximately 1.2¢/m^3 of delivered water.

A description of wind electric water pumping technology and its potential role in rural water supply is given in Appendix 3.

Bergey Windpower Co.

Bergey Windpower Co. was formed in 1977 and shipped its first wind turbine in 1980. Since that time it has delivered over 1,000 1 and 10 kW wind turbines to 47 U.S. states and 38 foreign countries. The wind electric water pumping systems supplied by BWC for the Naima project were a new application of the 10 kW BWC EXCEL wind turbine, which has been in production since 1983. The EXCEL wind turbine has been used in numerous rural electrification projects in developing countries.

II) PROJECT CHRONOLOGY

For its size and scope, the Naima Wind Project had an extraordinarily protracted implementation schedule. The following chronology highlights the complexity of this developmental aid project and the perseverance required to see it through to fruition.

1983-84 Project designed by CDER and the TA contractor, Research Triangle Institute (RTI).

8/85 Naima project tender issued by CDER through USAID/Rabat.

9/85 BWC submits an unsolicited proposal to SERI to support basic research and testing of wind electric water pumping systems. BWC informed that funding not available.

10/85 Bergey Windpower sends Naima project bid to Rabat via Emery Worldwide, who sends it to Mexico and loses it for five months. As BWC was the only respondent to the RFP, CDER officially receives no bids to tender.

8/86 New tender, with significant changes, issued by CDER through RTI in North Carolina.

10/86 RTI receives two bids, but only one, from BWC, has the required bid bond.

11/86 BWC asked to submit further cost breakdowns and informed that its bid "exceeded the cost estimate for the project by a considerable amount "

1/87 BWC asked to extend validity of bid bond.

2/87 Solar Energy Research Institute (SERI) issues an RFP for cost-shared research. One of the suggested research topics is wind electric water pumping.

3/87 BWC informed that CDER had canceled the Naima project due to its high cost.

6/87 BWC representative travels to Marrakech for discussions with CDER and USAID. BWC proposes contract modifications and price cuts that lower project cost from $200K to $140K. CDER agrees, verbally, to proceed with project and accept BWC recommendations. A portion of the savings come from integration of U.S. testing with the potential BWC/SERI cooperative research program in wind electric water pumping.

7/87 BWC notified that it would receive SERI funding for "Testing and Analysis of Small Wind Electric Water Pumping Systems" program.

8/87 BWC submits summary of Marrakech agreements via telex to CDER. Mechanics of revising contract not clear.

9/87 New CDER technical assistance contractor, IDEA, takes over for RTI.

10/87 Dynamometer testing of the BWC wind turbine alternator and pump systems begin at the USDA Agricultural Research Service facility in Bushland, Texas.

12/87 Upon CDER request, BWC submits contract modifications embodying the agreed changes.

1/88 CDER notifies BWC that it will not accept modifications relating to bonds, warranty and payment terms.

2/88 Field tests of the BWC wind electric pumping system begin at the USDA Bushland facility.

2-3/88 Negotiations concerning modifications continue.

4/88 Following USAID/Rabat intervention, CDER agrees to abide by most of the 6/87 Marrakech meeting agreements. BWC agrees to the differences.

4/88 CDER signs contract and sends copy, via surface mail, to BWC. Contract not received at BWC until 7/88.

7/88 CDER Technician undergoes training at BWC and West Texas State University (Head of the CDER Wind Section was to have been trained, but could not pass the required English proficiency test).

10/88 BWC engineer travels to Naima for site survey. Trip hastily arranged after BWC asks questions relating to the sites that CDER and TA contractor cannot answer.

11/88 BWC submits tower foundation and Ain Tolba tank construction drawings.

12/89 BWC ships equipment, less pump controllers and a few small items.

2/89 BWC notified that equipment has arrived in Naima.

3/89 BWC notified that civil works are completed and asked to arrange installation trip as soon as possible.

3/89 BWC ships balance of equipment via airfreight (at BWC expense).

4/89 BWC engineer and technician arrive in Marrakech to find out that 1)civil works will not be done for at least three weeks (DPA did not know they were to do tower foundations - only working on tank), 2) no arrangements for labor, tools or supplies have been made (in fact, no CDER technicians are available - one is on vacation and the other is on another installation, 3) DPA is not expecting the BWC supervisors, and 4) Ramadan is about to begin.

Over a 17-day TDY foundations are constructed, both turbines and anemometer systems are installed and the system at Dar El Hamra is completed and commissioned. The blades on the Dar El Hamra turbine are found to be unbalanced, so the unit is furled pending the installation of a balanced blade set. Ain Tolba can not be completed because the tank is only 50% completed and the diesel house is filled with the contractor's materials. Only five hours of operational and service training are completed.

5/89 BWC airfreights a replacement set of blades to Casablanca and CDER forwards them to Naima.

6/89 BWC's service subcontractor replaces blades at Dar El Hamra. Ain Tolba tank completed.

7/89 CDER, DPA, and BWC service subcontractor complete equipment installation at Ain Tolba. Both systems are operational for an Inauguration Ceremony (attended by the Minister of Energy and Mines) on 7/4/89.

7-8/89 Systems operate intermittently over next six weeks. IDEA consultant who is to do acceptance testing for CDER is unable to schedule this work due to vacation and involvement in a PV pumping project.

8/89 Representatives of USAID//Rabat and IDEA visit Naima sites, finding problems at both. Improper operating procedures (resulting in equipment damage at Dar El Hamra) and inadequate service support are identified. BWC service subcontractor is in process of modifying electrical subsystem on his own initiative. He is told to cease activities and shut both systems down pending arrival of BWC technician.

9/89 BWC technician travels to Naima, affects repairs and returns both units to operation. Replacement parts for damage done by improper operation of the Dar El Hamra system amount to approximately $1,500. Work is interrupted by need to assist CDER and IDEA staff in preparation of project presentation at CDER water pumping conference in Marrakech. Following the conference, the IDEA consultant and BWC technician travel to Naima for acceptance testing. Activity takes two days. IDEA consultant submits memo to CDER pointing out numerous technical complaints about systems and stating that insufficient data was taken to verify compliance with performance specifications. Staffer recommends systems not be granted Provisional Acceptance. Five days later the MREDP contract expires.

11/89 BWC prepares a response to the IDEA consultant memo and submits formal request for reconsideration of provisional acceptance, along with related support materials, to CDER. No response or information on status of systems received.

12/89 USAID/Rabat program manager requests TA support from USAID Office of Energy to bring BWC technicians back to Morocco to resolve technical and acceptance problems. Word is received from DPA that systems are not working and BWC support subcontractor is not attempting repairs. BWC hires Moroccan graduate student at University of Oklahoma on part time basis to improve communication with various parties in Morocco.

1/90 USAID Office of Energy offers to support requested TDY.

2/90 BWC engineer and technician travel to Oujda. Minor electronic problems found at both sites - a total of three hour's labor is required to return systems to operation. For the next 10 days performance data is taken (verifying that specifications are met) and numerous training sessions are given. BWC releases its original support subcontractor, hires and trains new group that includes an electrical engineer. Station battery charging systems are modified by BWC by removing the micro wind turbines and replacing them with photovoltaic panels. BWC had formally requested that a CDER official come to Naima on 2/25/90 for acceptance, but receives no response from CDER. CDER does supply the services of an engineer and a technician.

3/90 Dar El Hamra system experiences failure of control card during storm related high winds. New BWC support contractor responds and contacts BWC. Problem diagnosed as an underrated surge arrestor - higher rated replacement must be sent from U.S. BWC sends parts. Total down time is nineteen days. Local support of systems hampered by refusal of original BWC support subcontractor to release spares and diagnostic equipment to new support subcontractor. Several weeks later Ain Tolba system shuts down due to low station battery (finally diagnosed as reversed battery leads resulting from operator's unauthorized use of charging system for recharging car batteries).

4/90 For the first time, BWC receives Site Inspection Reports - prepared by new support subcontractor.

6/90 Systems accepted by CDER. By prior agreement the equipment is now to be passed to DPA/Oujda. The one-year warranty also officially begins.

III) PROJECT PROBLEMS

Although ultimately successful, the Naima Wind Project was a long, difficult, and often frustrating ordeal for Bergey Windpower Co. and the other project participants. In comparison to a standard commercial sale of two 10 kW wind turbines, the Naima Wind Project required the time, money and effort of several dozen projects. It was also a tremendous learning experience that both advanced the project implementation skills at BWC and provided potentially valuable insight into the problems that can befall USAID development projects. This section is an attempt to identify and explain some of the major problems encountered, from the contractor's viewpoint, in the execution of the project.

1. Lack of Host Agency Commitment to the Project

The Naima project evolved out of a political need to do a renewable energy demonstration program in Naima Commune and a desire on the part of the original CDER TA contractor (RTI) to advance the technology of wind powered water pumping. The RTI TA team designed the project and saw it through most of the protracted contracting cycle. CDER, however, never really adopted the project and provided only limited support for the project's implementation.

The exact reasons for CDER's overall reluctance to support the project were never formally declared, but were most likely due to a variety of factors and circumstances. One major factor was the legacy of a previous costly and unsuccessful wind electric installation undertaken within the MREDP and funded by USAID. CDER may have felt that they were being saddled with another "white elephant", even though the design, architecture, and components of the Naima systems were substantially different from the previous one. Risk adverse though they might have been, CDER was probably reluctant to officially oppose the Naima project because it was part of the total USAID program support package for CDER.

Other factors which possibly contributed to this reticence were: the larger than expected cost of the Naima project (40% higher than CDER had optimistically budgeted); often fundamentally different interpretations by CDER from that of USAID and the TA contractor on the nature and level of support that CDER was required to provide to the project; the distance of the site from CDER headquarters in Marrakech (exacerbated by CDER's limited travel and per diem budget); the scheduling of system installation during Ramadan (making physical activity during the day very stressful); CDER's preoccupation with the construction of it's new building; low morale on the part of the CDER staff; a basic insecurity on the part of the Wind Section in supporting the technology; and, lastly, the influence of a TA staffer who himself was not enthusiastic about the project and was preoccupied with other activities. Many of these issues are discussed in detail below.

The result was that the project was not given the priority, attention, and assigned chain of responsibility it required for efficient and effective implementation. Credit must be given, however, to CDER Wind Section technician, Mr. Fatallah Affani. He was a consistent supporter of the project and was an important contributor.

CDER's lack of commitment was countered by BWC's and the USAID project manager's strong desire to see the project through to fruition. The latter's support was particularly noteworthy because he was willing to press CDER to complete the project so that "we can find out whether these things (wind electric pumping systems) are any good." Without this pressure, CDER would have scrubbed the project and the basic question, at least in the Moroccan context, would have gone unanswered.

2. Weak Host Agency Technical Staff

It was clear that the management of CDER's Wind Energy Section was insecure in its approach to the Naima project, probably stemming from a relatively weak background in wind electric technology and a lack of experience with implementing field projects. Though several staffers were degreed engineers, their level of training was below that normally found in U.S. trained engineers. Their training in the field of wind energy came entirely from USAID under the MREDP. This training had been generally unstructured, short in duration, and, because it was conducted in

English, difficult for the Moroccans to assimilate. Unlike solar technologies, there is little in the way of technical reference material and regular training courses available for wind energy. This makes it difficult to organize an effective training program. Fortunately, by virtue of his proficiency with English, Mr. Affani, was assigned to the Naima project and was sent to the BWC factory in the U.S. for training. Though not a degreed engineer he became the in-house "expert" in the technology underpinning the Naima project.

The Moroccan engineers also seemed to be less enthusiastic about field work than their U.S. counterparts and showed little interest in the details that determine successful project implementation. This may have an institutional foundation in that Moroccan engineers tend to leave field work to technicians and devote their activities to "white-collar" work. This is believed to be a contributing factor in the disinterest in the Naima project on the part of the head of the CDER Wind Section, who was supposed to be responsible for overall management of the project. His apathy caused many problems and was very frustrating for BWC.

3. Immature Technology

The project RFP favored a wind pumping system architecture that was not commercially available, although it had been experimented with by researchers in Europe and the United States. A previous, and relatively unsuccessful, MREDP project at Sidi Bounouar had utilized a wind turbine/battery/electric pump system. The Naima project RFP encouraged the use of the more advanced direct link wind electric pumping system.

Bergey Windpower viewed the project as an opportunity to broaden the application of its wind turbines and enter the potentially large water supply market. Due to the poor business conditions for U.S. renewable energy companies beginning in 1986, however, BWC did not have the resources to independently research and commercialize this technology. Following the release of the original Naima RFP in 1985, BWC approached the Solar Energy Research Institute (SERI) with an unsolicited proposal for experimental work in the field of wind-electric water pumping. SERI was not able to accommodate BWC's request at the time but did add the topic to a planned solicitation for cooperative SERI/industry research programs.

Since the Naima contract award was delayed more than two years, BWC was fortunate to win a contract with SERI under this cooperative test program in time to apply the results to the Naima project. In fact, BWC obtained SERI agreement to adapt the cooperative research program to include the specific pumps intended for Morocco. Thus, BWC and USAID obtained a U.S. test on the equipment prior to shipment to Morocco, and SERI obtained a market focus on a basic science project. Also, since the SERI work was integrated with an active project, commercialization of the newly developed technology was achieved in very short order. Integration of the projects also allowed BWC to lower its USAID/CDER project bid by transferring the cost of the U.S. testing (deemed absolutely necessary by BWC) to the SERI project, at no additional cost to SERI.

In terms of technology, the SERI/BWC (cosponsored) program was critically important to the Naima project. Without the basic research into variable speed induction motor power transmission and high speed pump operation afforded by the SERI support, the equipment selection and control strategy for the Naima systems would have been a shot in the dark. Thus the equipment finally sent to Morocco was a third generation pump configuration drawn from numerous lessons learned at the USDA facility where the SERI/BWC work was performed. The SERI support also allowed the two leading U.S. experts in wind powered water pumping, Dr. Nolan Clark of the USDA and Alan Wyatt of Research Triangle Institute (who, incidentally, originally designed the Naima project while RTI had the MREDP TA support contract), to work on wind electric pumping technology development. Finally, the higher average wind speed and frequent severe storms at the USDA Bushland, Texas test site allowed accelerated testing of the pump configurations.

The development of the technology for Naima delayed the shipment of equipment to Morocco by approximately nine months. Shipment of the pump control systems was further delayed by questions concerning control requirements at elevated frequencies and by an eventually abandoned attempt to charge the 12 VDC station battery, used primarily to power onsite instrumentation, from the wide-ranging wind turbine output. The 50W 12 VDC wind turbine charging system chosen as the fall-back approach also proved problematic and was eventually

(February 1990) replaced with 50W PV modules.

It is worth noting that BWC was repeatedly advised to avoid referring to the equipment as being prototypes. It was felt that leading technology development was something that USAID did not want to do and that any reference to the prototype nature of the equipment would raise red flags with the Rabat mission staff. CDER also did not appreciate the pioneering nature of the project and consistently took a simplistic approach to field operational support.

4. USAID Procurement Regulations

While USAID procurement regulations play a beneficial role by enforcing a competitive bidding environment, their lack of flexibility can hinder resolution when difficulties arise. In the first Naima procurement, for example, USAID could not make an allowance for a lost bid package and had, therefore, to repeat the entire tendering process. More seriously, the process could not accommodate and resolve the gulf that arose between budget and bid in the second round. It is now known that BWC's bid was over twice the amount budgeted by CDER. There were substantive reasons for this, but the fact that buyer and seller could not, under USAID regulations, openly discuss the procurement prevented resolution and doomed the project to cancellation. It was only after the process was opened up months later that the issues underlying the cost discrepancy could be aired and evaluated.

Once the process was open, it was relatively easy to pare costs. An example was the substitution of a 5% payment withholding for the one-year warranty period for the originally specified performance bond. While it was reasonable for CDER and USAID to require a performance bond, particularly in light of the perceived lack of manufacturer support on the Sidi Bounouar wind project, this proved to be a difficult commodity to supply. CDER and USAID did not know that the bonding companies had tightened their requirements substantially in the latter half of 1986. They also did not seem to appreciate that after the loss of the U.S. tax credits in late 1985 and the sudden drop in oil prices two months later, the balance sheets of U.S. wind companies showed substantial erosion. This made obtaining the required bonds directly very difficult.

Another Naima project bidder was not able to obtain a performance bond and, therefore, had its presumably otherwise qualifying bid rejected as "non-responsive." BWC was only able to obtain the required bond by bringing in a large utility subsidiary as a partner on the project. This company provided the bid bond and was prepared to provide the performance bond, but their attendant management oversight came at a high cost. As a result, the performance bond alone raised the BWC bid by over 20%. It would have helped both buyer and seller if these market factors and their impacts could have been discussed during the tendering process.

It is possible that the inclusion of an "alternative bid" clause in the RFP or the creative use of the "best and final offer" process could have opened the process while still adhering to the USAID regulations.

5. Hampered Communications

The progress of the Naima Project was hampered by several types of communications difficulties. The most serious of these was the language barrier between the Moroccan participants and BWC. Moroccans speak Arabic and French, but few are versed in English. No one at BWC spoke French, so interpretation was always necessary. The staff of RTI and later IDEA provided this service in correspondence, and CDER's technician, Fatallah Affani, provided translation during TDY's. This added overhead costs to the project and also eliminated the possibility of the BWC project manager resolving differences with CDER through direct communication with the Director General of CDER.

Another significant impact of the language problem was that the BWC-produced technical manual for the Naima systems was in English, and thus not understood by the people directly responsible for field service. BWC had originally budgeted for translation of the manual, but this work was cut out to reduce project costs in the June 1987 contract negotiations. CDER verbally agreed to translate the critical chapters of the project manual, but has not yet done so.

Another communications problem involved Moroccan telephone and telex equipment. It would sometimes require 6 days and over 40 attempts to complete a telephone call to Marrakech. The telex at CDER was often inoperative causing delays of up to several weeks. Mail and courier service was also problematic. In 1985 DHL did not service Morocco (due to Customs clearance difficulties) and the only national service that did, Emery, proved to be unsatisfactory. (Such services have improved notably of late.) The mail service is very spotty; sometimes airmail letters take only 10-15 days, while other times they can take two months. Most of the official documents sent by CDER to BWC took 6 to 8 weeks to arrive. BWC always used courier services; CDER never did. It is estimated that BWC spent over $5,000 in telephone, telex and courier service charges on the $120,000 Naima Project. This is 20 to 50 times the amount typical for a domestic project of a similar size. If labor costs were factored in, the communications cost for the Naima project would probably exceed $30,000.

6. Customs Clearance

Like many LDC's, Morocco puts a significant duty on imported equipment and has a large bureaucracy enforcing its import controls. On a government project like Naima, it is standard practice to receive a waiver of duties, but the actual process of clearing officially duty-free imports is laborious and slow. The delay of customs clearance is readily accommodated in project scheduling and does not represent much of an impediment in scheduled equipment deliveries. The same cannot be said for unscheduled or "last-minute" deliveries that are always necessary in field projects.

On two occasions, equipment and materials hand-carried by BWC personnel were confiscated at entry into Morocco and were not cleared by customs for 6 to 9 days. Since both of these TDY's were 14-day missions, these delays severely affected productivity and scheduling. On the last TDY in February 1990, the equipment brought in was known several weeks beforehand and arrangements were made with CDER to have the required authorizations available at entry. This effort took 8 international telephone calls, 9 telexes and 4 facsimiles, but enabled the equipment to clear in about 2 hours.

In January of 1990, Morocco added wind and solar energy equipment to the list of duty-free items used in rural development. This should help streamline the importation of items required for service support.

7. Distance Between CDER and Project Site

Most all of CDER's field projects have been sited within 150 km of Marrakech. Naima, on the other hand, is over 1,000 km from Marrakech and requires an 18-hour train ride or an expensive five-hour flight. On arrival in Oujda, a government vehicle had to be arranged to travel 25 km to the project site. These logistics and the travel time required reduced site visits to less than necessary. This hampered planning and installation, and is presently hampering the monitoring of performance. Had Naima been closer to Marrakech, for example, CDER might have verified the completion of the civil works before asking BWC to make its installation TDY.

8. High Cost of Travel between U.S. and Morocco

An economy non-excursion round-trip airline ticket from Oklahoma City to Oujda, Morocco is over $2,000. This discouraged planning meetings, secondary installation trips (eg., after Ain Tolba tank was finished) and service calls. It is amazing that CDER expected a U.S. supplier to provide direct service support of the systems with these travel costs.

9. Inadequate Project Management in Morocco

CDER did not provide the local project management function needed to fulfill its part of the contract with BWC, relying instead on the services of the TA contractor IDEA, Inc. The Marrakech staff of IDEA provided liaison with BWC and responded to "crises" effectively, but seemed to defer to a CDER project management that just wasn't there. The result was that no one in Morocco was effectively in charge of the Naima project. BWC exacerbated the problem by wrongly concluding that IDEA had assumed the responsibilities contractually mandated to CDER.

10. Lack of BWC or USAID Leverage over CDER

The contract for the Naima project was directly between CDER and BWC, with USAID only writing the checks at CDER's direction. The contract gave CDER considerable financial leverage to ensure that BWC performed as specified. It did not, however, contain any leverage for either BWC or USAID to ensure that CDER performed. It was not, in hindsight, a contract that BWC should have signed. There turned out to be no way that BWC or USAID could compel CDER to shoulder its responsibilities or treat BWC equitably.

11. Change of TA Contractors

The original MREDP technical assistance contractor, RTI, was technically strong in the field of wind energy. This, in part, lead to the development of a project plan involving wind technology. The change in TA contractors, for whatever beneficial reasons, had the negative effect on the Naima project of reducing "in-house" expertise in wind energy. IDEA did upgrade its wind energy capability with a new hire in 1989.

12. Project Not Designed with Support in Mind

The plan in the RFP for operationally supporting the Naima wind was that for one year CDER would notify the contractor of problems and the contractor would, in turn, dispatch a technician to affect repairs. This is not a workable scheme for mature technologies let alone immature ones like wind electric water pumping. When BWC responded to the RFP with an "over budget" bid that included U.S. testing, a large spares holding, an expensive technical manual, and the provision of a local support subcontractor, the project was nearly canceled.

13. Failure of the BWC Support Subcontractor to Perform as Intended.

BWC suggested the idea of establishing a private sector support capability in Morocco to provide the first line of technical support for the systems. USAID and CDER concurred with this idea, but CDER gave BWC the responsibility to select, train, and support the local Moroccan firm. BWC chose Maroc Aero Energie (MAE) of Oujda over other wind energy firms in Morocco on the basis of MAE's proximity to Naima, the resources of its parent company (a combination pump equipment dealership and electric motor repair shop), and its previous experimental work in wind electric water pumping. The head of MAE and his crews participated in the installation work in April and June of 1989, and BWC entered into a one-year support contract with MAE at that time. Although only a few hours of training were accomplished during April, MAE showed its capabilities and value in June 1989 by successfully replacing the turbine blade at Dar El Hamra. Later in the month, CDER used MAE to complete the system installation at Ain Tolba.

Unfortunately, problems with MAE began to appear shortly after the June inauguration of the systems. In addition to responding to reported problems, BWC had contracted MAE to visit the Naima sites every week for the first 2 months of operation, then every 2 weeks for the next 4 months, and then every month for the balance of the warranty period. Formal site inspection reports were to be submitted to BWC and CDER following service incidents or a scheduled inspection. However, these were not forthcoming, and because of the language barrier BWC was not able to directly contact MAE to ascertain the status of the equipment. Efforts to obtain information through CDER were largely unsuccessful. BWC pretty much lost contact with the equipment until USAID and IDEA visited the site in late August 1989.

That MAE was operating the systems (and advising the local operators to do likewise) in an inappropriate and risky (to the equipment) manner showed MAE did not really understand the AC pumping system and was unprepared to deal with simple electronics problems. The problem was compounded by MAE's desire to assert their own engineering capabilities and correct what they perceived to be system deficiencies without involving BWC in any way. Months later, during the February 1990 TDY, it was finally determined that MAE was trying to prevent the systems from overspeeding by adding series resistors to the power circuits when a simple adjustment of a potentiometer was all that was called for. It was this stubbornness on the system design issue, the lack of electronics experience and a nonchalance about the operational status of the equipment that finally led BWC to obtain a new local support contractor. This was accomplished during the February 1990 TDY, with very satisfactory results.

14. Limited Resources of BWC

BWC's limited financial resources limited it's aggressiveness in taking control of the Naima installations in the summer of 1989 to ensure that the operational support was at it should be. Also, the BWC project manager could have been more diligent in ensuring that the SERI supported research work progressed in accordance with the original SERI project schedule and the scheduling requirements of the Naima project. The delay in shipping equipment, and particularly, the pump controllers, was due primarily to insufficient attention to the two projects.

IV) LESSONS LEARNED

The following subjective list of lessons learned from the Naima project is provided in the hope that it will give project planners insight into the crafting of effective renewable energy development programs. The reader is reminded that the author 1) is not an LDC development professional, 2) was not privy to all aspects of the MREDP, and 3) had rather a frustrating time of an MREDP project.

1. The situation at CDER has served to delay the diffusion of renewable energy technologies in Morocco.

The current market for photovoltaic and wind energy equipment in Morocco is principally for decentralized applications spread throughout a number of public sector agencies and organizations. CDER was established under the premise that a centralized agency was needed to provide technical support to these various organizations, as well as to the private sector.

As the centralized public authority with responsibility for implementing renewable energy projects, CDER has, however, increased the distance between suppliers and users and injected additional requirements for project success largely because of its institutional weaknesses, poor morale, and apparent apathy. If CDER had evolved into a storehouse of specialized technical and managerial expertise then it could well have been an effective facilitator of technology diffusion to other Moroccan organizations. As it is, however, CDER imparts a disruptive influence that makes renewables appear less attractive to the marketplace and tends to scare private sector participants, both foreign and domestic, away. The end result is that CDER is being side-stepped or avoided by other Moroccan agencies and private investors.

In BWC's case it would have been more efficient and far less frustrating if USAID had supported a project subcontracted by the technical assistance contractor and coordinated directly with the real customer, DPA in Oujda. DPA was consistently enthusiastic about the Naima project and, within its bureaucratic limitations, always responsive and helpful. DPA also represents a continuing market for wind electric pumping systems.

2. USAID should always maintain leverage with host country institutions it is underwriting.

When BWC became involved with the MREDP in 1987, it discerned that USAID viewed CDER as a problem child. USAID was dissatisfied with the staffing, lack of direction, programmatic results and probably a lot of other things at CDER. However, in spite of the fact that USAID funded much of CDER's activities, it could not force CDER to shape up because the MREDP gave CDER almost complete programmatic control. The USAID program manager had some influence with CDER, but the lack of real leverage allowed CDER to chart an independent course.

Two examples provide support for the notion that USAID should have kept its hand on the tiller. The first is that USAID was powerless to force CDER to honor its contractual commitments to BWC or work to resolve disputes. The USAID project manager, who made a strong personal commitment to resolve the acceptance dispute and insure that the people of Naima Commune got the water they needed, was reduced to indirect maneuvers and having to ask for assistance from the USAID Office of Energy. After spending over $9 million to establish CDER and give it something to do, USAID should not have been in this position.

The other example is less obvious, but more significant in its impact. It is clear that USAID needed to provide CDER with technical support early in the MREDP. One might reasonably expect that the need for this support would diminish with time as CDER matured. However, this is not how things turned out. Based on stories from the early years of the project and BWC experience with the last two years of the project, it appears that CDER's capabilities declined in the latter part of the project and it relied increasingly on the TA contractor to perform substantive functions. It was, therefore, principally IDEA that was maturing as a project developer rather than CDER. From the outside IDEA seemed too much of a hand-maiden for CDER. While this was easier on CDER and arguably better for USAID and the TA contractors, it was certainly counterproductive to the original intent of CDER because it allowed the working departments of CDER to atrophy. Due to the structure of its relationship and contract with CDER, USAID could not hold project funding as ransom to bring about a redirection of CDER or a change in management. Likewise, since IDEA worked for directly for CDER and not USAID they too were powerless to force CDER to shape up and take more responsibility for its programs.

It is said that the German aid agency, GTZ, takes a much harder line with its host country projects. If a host country agency that GTZ is supporting begins to handle a project in a way that GTZ thinks jeopardizes the realization of its goals, it is able and prepared to stop the project until the misdirection is corrected and, if necessary, to withdraw its support completely. After BWC's experience with the MREDP, this approach has a certain appeal.

3. USAID programs, particularly when they involve maturing technologies or emerging markets, should maintain a high degree of flexibility.

Since the USAID project pipeline typically takes 2-3 years the MREDP was designed from renewable energy precepts dating back more than a decade. In the late 1970's the conventional wisdom was that renewables needed research, development and demonstration to adapt them to the LDC environment. However, by the time MREDP came online and up to speed, renewable energy products and suppliers had matured substantially and the need for research and adaptation was correspondingly diminished. Certain renewable energy technologies, such as solar hot water, photovoltaics and mechanical windpumps, were arguably ready for commercialization in 1982. By the midpoint of the MREDP in 1986 it was clear that the research focus of CDER only made sense if CDER was attempting to develop new and unique technologies. Through the hard fought efforts of the incoming USAID project manager the focus or the MREDP was changed, much to the displeasure of CDER, to commercialization and technology transfer in 1986-7.

The difficulty in restructuring a long lived project from a research to a commercialization focus was a problem with a number of the 1970's generation USAID renewable energy programs, including those in Morocco, Egypt, India, and Sudan. It is also probably fair to say that the host country participants were more resistant to mid-course corrections than USAID. This was certainly the case in Morocco, where the USAID project manager had to continually press the CDER management to change the focus of the project.

4. USAID should institutionalize operational support in a rigorous manner for use in field projects aimed at introducing new technologies.

On the Naima project the only planned and budgeted provisions for operational support were a spares holding ("suitable for three years"), a technical manual (in English), and an unrealistic one year warranty statement. In fact, more verblage in the Naima project RFP was given to the subject of the use of U.S. flag air carriers than to all aspects of operational support. But it is precisely operational support, or the lack thereof, that has been the Achilles Heel of USAID and other donor LDC rural technology projects. Part of USAID's phobia against technology and hardware projects is due to nondecaying anecdotes about failed and decaying field hardware projects.

It would seem fairly straightforward to produce a guide on operational support fundamentals for USAID project planners and managers. Procurement boilerplate could also be written that would ease the incorporation of these fundamentals into RFP's. There seems little sense in having to reinvent the wheel on each project and run the risk of this important element being given short shift. It would also reduce the likelihood of under-budgeting projects, as CDER did, because operational support was not carefully considered. Particularly in small projects, the high cost of setting up the infrastructure to provide operational support for a new technology can be a significant percentage of total project costs.

5. Multi-agency governmental and private sector cooperative development programs can be effective and efficient in adapting renewable energy technology to developing countries applications.

It would have been very difficult for Bergey Windpower, DOE/SERI, or USAID alone to identify the technology development opportunity of improved wind-powered water pumping and implement a comprehensive RD&D program that resulted in a market-ready LDC product. Just as an inter-disciplinary study generally provides more holistic results, the different scopes of activity of the major

Naima project participants provided a rounded effort that was more likely to produce a commercially viable technical result. These are groups that seldom work together, but have symbiotic strengths and complementary goals. USAID serves clients with much more pressing energy problems than the U.S. now has and at the mission level the Agency is lacking in sufficient energy technology expertise. The U.S. Department of Energy (DOE), with its extensive technical capabilities, is coming to realize that it has a role to play in the international energy arena, and its programs, under a new administration, are focusing on commercialization. The U.S. renewable energy industry for its part has to look at LDC markets for growth in an era of low cost and abundant U.S. conventional energy supplies and lower cost conservation alternatives.

Being more competitive in adapting technology to local needs, such as applications development and technology transfer, through multi-party, private/ public sector efforts may be an effective and politically palatable way for U.S. firms to compete with the heavy handed tied-aid programs practiced by foreign donor organizations. Viewed in this light, the Naima project and the structurally similar USAID PACER project in India may hold the basis for improving the competitiveness of U.S. renewable energy companies.

In return for its funding, DOE/SERI required that the technology developed under the cooperative agreement with BWC be made available to the entire wind industry. A similar approach has been taken by DOE/SERI with the $12 m Advanced Turbine Initiative (large machines) and is likely to be followed in most future programs. Cooperative funding ensures that projects are efficient and commercially oriented. It would seem possible for this approach to be extended overseas. Further, it would seem beneficial for DOE, USUSAID, and industry to cooperate with each other in a more direct manner and share the results of these efforts with, or invite the programmatic participation of, LDC host country market developers. USAID has operated under a PASA with DOE's predecessor agency ERDA in the past and it may be time to explore reestablishing this bridge.

6. USAID should be developing larger scale implementation projects for renewable energy technologies.

One of the chief advantages of renewable energy technologies is that they often lend themselves to local content and, therefore, can provide economic development benefits in addition to their sustainability benefits. Local production of renewable energy equipment also establishes a firm base for operational support of the equipment involved, one of the main obstacles to be overcome in introducing new technologies. Local production, however, requires the establishment of a sustaining market of sufficient size to provide a reasonable return on the investment required to set up a manufacturing or assembly operation. Demonstrations of one, two, or ten similar renewable systems are a necessary, but insufficient prerequisite for attaining a sufficient market. To complete the process of technology transfer, USAID should weigh the cost and benefits of a follow-on project that serves to increase the market penetration and "primes the pump" for non-subsidized commercial market development.

7. Wayward development projects offer a tremendous learning experience.

As frustrating and expensive, in both time and money, as the Naima project was, it was perhaps invaluable as a learning experience for a small and relatively inexperienced firm such as BWC.

V) RECENT OPERATING EXPERIENCE

Acceptance testing for the wind equipment was performed by BWC and CDER staff during the February TDY. The BWC supplied pumping systems were required to demonstrate performance at least 80% of that specified in the tender. Since the actual dynamic pumping heads at the two sites turned out to be over 20% higher than specified, however, the performance requirements were correspondingly reduced. The acceptance testing showed that the equipment met the specified performance requirements and, in fact, showed less derating for the higher head than would be expected. The higher dynamic heads did increase cut-in wind speeds (minimum wind speed required to initiate pumping) about 1-2 m/s, which has the adverse effects of reducing pump operating time and increasing the hydraulic hammer affect at cut-in.

Some operational problems were experienced in March when high winds tripped underrated lightning surge arrestors, causing both systems to be down for nineteen days while replacement parts were shipped from the U.S. Other than this interruption the operation of the systems has been satisfactory. The equipment has now been turned over to the local DPA and is being monitored and maintained by a BWC trained local business, Spolyten S.A. of Oujda. Communications and cultural understanding have been greatly improved through the services of a Moroccan graduate student at the University of Oklahoma, located in Norman, who now provides liaison between BWC and Spolyten.

The following summaries cover performance through September 20, 1990:

Ain Tolba:

Since April 3rd, the date the surge arrestor problem was corrected, the wind pumping system at Ain Tolba has been 100% available. This puts the cumulative availability at 91.2% since the system was recommissioned in February. Since that time over 3.7 million gallons of water have been pumped. The average daily volume of 17,470 gallons (66.2 m^3) is 100.2% of the performance target specified by CDER and corrected for the higher head. This figure includes the nineteen days downtime in March. The daily water volume has increased approximately 220% over that previously pumped by the diesel. Perhaps the best indicator of success is that the diesel pump has not had to operate since the repairs were made on April 3rd.

Dar El Hamra:

At Dar El Hamra, the wind pump system has been approximately 97% available since April 3rd due to thermal breaker trips. This puts the cumulative system availability at 88.8% since the system was recommissioned in February. Cumulative pumped volume is not available for Dar El Hamra due to a problem with flow metering, but DPA/Oujda reports that sufficient water has been supplied to Rmilat since April.

Thus the systems seem to be performing as intended and have carried the Commune users through the dry season. The project has also spawned non-subsidized commercial sales of wind electric pumping systems in Morocco and neighboring countries. Current projections of the market development indicate that local production of BWC wind turbines in Morocco may be justifiable within a few years. While it is far too early to make broad claims about the reliability and O&M costs of wind electric pumping systems the experience to date is sufficient to show that the potential for a more sustainable community water supply option.

Acknowledgements

Bergey Windpower would like to thank the following organizations and persons for their assistance in making the Naima Wind Project the successful demonstration project that it is: the U.S.-Agency for International Development Mission in Rabat, the U.S.-A.I.D. Office of Energy, EPIC, the U.S. Department of Energy, the Solar Energy Research Institute, U.S.D.A./Agricultural Research Service, the Alternative Energy Institute, DPA/Oujda, Spolyten S.A., Stephen Klein, Alan Wyatt, and Mohammed Lahlou.

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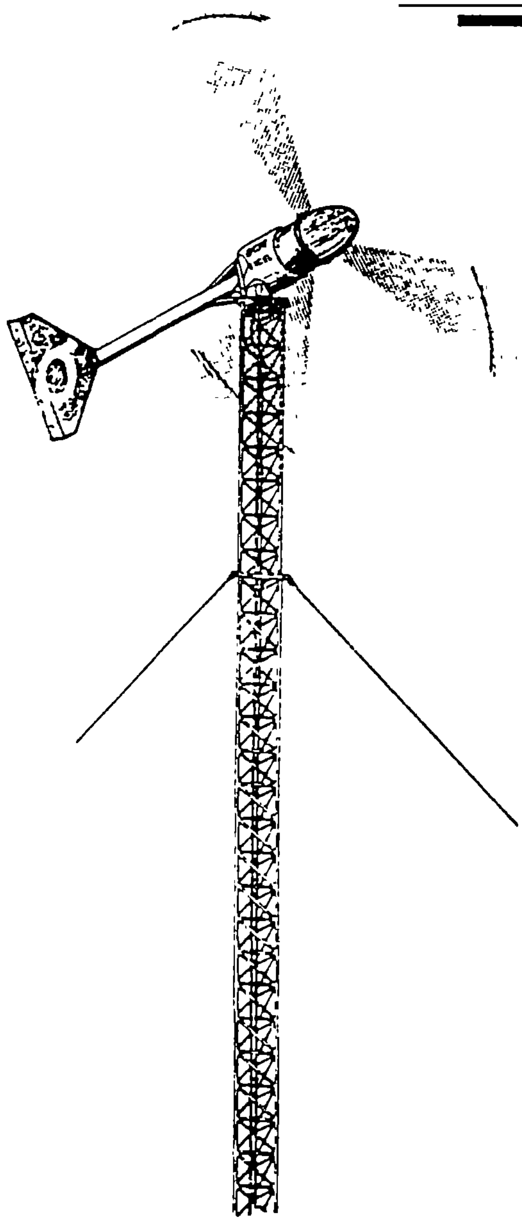
APPENDIX 1

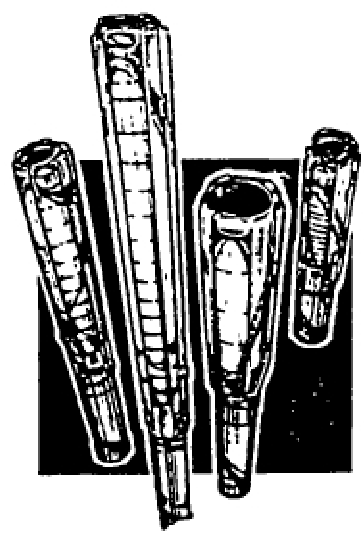
EXCERPT FROM THE NAIMA PROJECT MANUAL

Please note that this material was prepared in late 1988 and, therefore, does not reflect the higher than expected pumping heads that actually existed at the sites.

NAIMA PROJECT MANUAL

BERGEY WINDPOWER CO.





Description of Systems

1. Project Overview

The Naima Commune Water Pumping Project is a water supply enhancement and renewable energy demonstration project implemented by the Centre de Developpement des Energies Renouvelables (CDER), an agency of the Government of the Kingdom of Morocco, with support from the U.S. Agency for International Development (USAID).

In the Naima project two advanced wind-electric water pumping systems have been retrofitted to an existing 14 km water supply network serving four douars (settlements) with a population of approximately 4,000 people. The original system relied on diesel powered pumps, but water resources were underutilized because the Commune members could only afford limited operations and maintenance costs. The diesel pumps were also prone to breakdowns.

1.1 Site Description

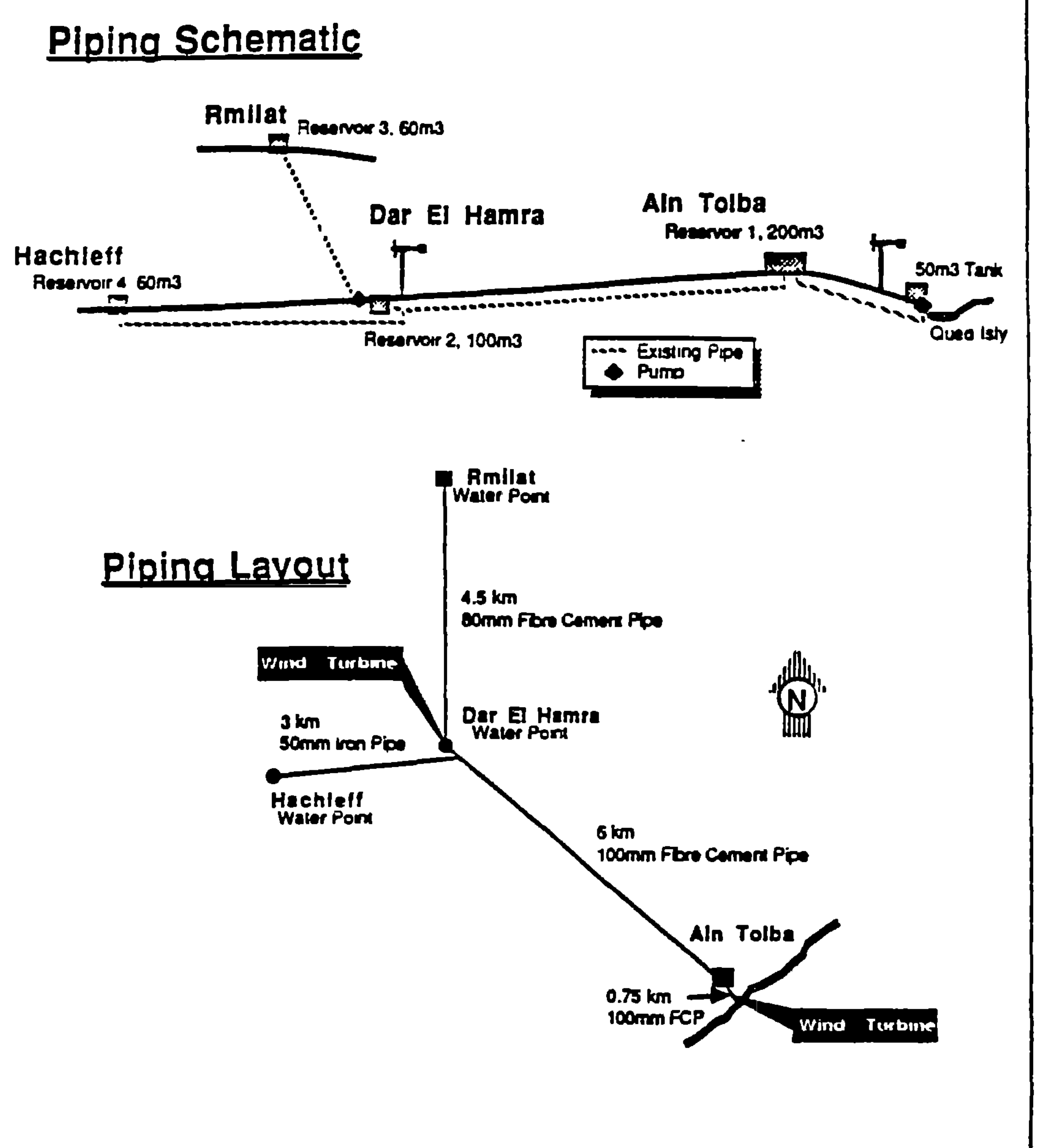
The Commune Rurale (CR) de Naima consists of some 200 km^2 of open flat land in the Oujda Province, in northeast Morocco. The geographic center of the Commune lies about 25 km southwest of the city of Oujda. The total population (1982) of the Commune is 9,109 widely dispersed in small douars of 20-40 families. There are some 16 public water points in the Commune, including typically, a diesel pump, a 50 m^3 reservoir, a livestock water trough and faucets. Drilled or hand dug wells currently serve 11 water points. Four are served by water gravity fed from other communes, and one is served by a solar pump.

1.2 The Current Pumping Systems

The Naima Commune water distribution system is shown in Figure 1. Water is pumped from a spring at Ain Tolba (next to the Oued Isly) with a 6.25 bhp Petter PH1 diesel engine/single stage centrifugal pump to a 200 m^3 reservoir some 750 m away. The static pumping head is about 18 m. The current source output is 4-5 liters/sec. From this reservoir water flows by gravity 6 km to Dar El Hamra, to a 100 m^3 partially buried concrete tank. A water point at Dar El Hamra is served from this tank. Before reaching the tank, part of the water is diverted to flow 3 km by gravity to a 60 m^3 reservoir and water point at Hachleff. Also from Dar El Hamra water is pumped from the 100 m^3 tank to Rmilat, with a static head of 80 m. A 6.25 bhp Petter PH1 diesel engine/multistage horizontal axis Grundfos pump provides the pumping power. This pump, however, has been broken for the last two years, so the people of Rmilat have had to fetch water from Dar El Hamra.

The pumping rates have been estimated to be 3 liters/sec at Ain Tolba and 2 liters/sec at Dar El Hamra. At Ain Tolba the operator estimated that he ran the pump 2-4 hrs/day in the winter and 5hrs/day in the summer. At Dar El Hamra the operator estimates that he ran the pump 2hrs/day in the winter and 3hrs/day in the summer. In both cases pump operation was limited by the funds available for fuel and upkeep.

Through surveys with the system operators and the local population, the CDER has attempted to determine how much water would be used if pumping costs were not a constraints. CDER has estimated that the actual demand for Ain Tolba is 71 m^3/day in the winter and 100 m^3/day in the summer. They have estimated the actual demand at Dar El Hamra to be 26 m^3/day in the winter and 37 m^3/day in the summer. These amounts are 71-119% higher than the deliveries presently provided by the diesel powered pumps.



Commune De Naima Pumping System

1.3 The New Pumping Systems

Following a competitive procurement in 1987, a contract was awarded to Bergey Windpower Co. (BWC) of Norman, OK, in April, 1988 to supply two wind-electric water pumping systems for the Naima project. Both systems use new wind turbine technology developed by BWC which allows centrifugal pump motors to be directly driven by the electrical output of a wind turbine, without need for batteries, inverters, or complex controls. The development of this technology was partially supported by the U.S. Department of Energy and testing has been performed in cooperation with the Agricultural Research Service of the U.S.D.A.

Both of the pumping systems are powered by a 10 kw BWC EXCEL-PD wind turbine installed on a 24 m guyed lattice tower. Although the water pumping version of the BWC EXCEL is new, the wind turbine itself is well proven in 350+ installations worldwide. At Ain Tolba the wind turbine drives a five-stage Grundfos 80S50-5 submersible pump installed in a specially constructed 50 m^3 tank adjacent to the existing diesel pump building. Due to the complex nature of the local terrain the wind turbine was installed approximately 220 m from the pump.

At Dar El Hamra the second wind turbine drives a twenty-six-stage Grundfos 25S50-26 submersible pump installed in the existing 100 m^3 tank. In both cases the new pumps are installed in parallel with the existing diesel pumps so that the diesel pumps can provide back-up in the event of extended wind lulls or wind turbine malfunction. Both sites are equipped with instrumentation for monitoring wind characteristics, energy production, pump performance, and operating hours.

The new 50 m^3 tank at Ain Tolba and the wind turbine tower foundations were constructed by the Delegation Provinciale d'Agriculture (DPA) in Oujda. The wind turbines, pumps and instrumentation were installed by BWC, CDER and Maroc Aero Energie of Oujda. The systems were inaugurated on July 4, 1989. The diesel system at Dar El Hamra has not yet been repaired, so the wind turbine is providing water to Rmilat for the first time in over two years. Operational support and maintenance for the turbines is being provided by Maroc Aero Energie.

1.4 Expected Performance

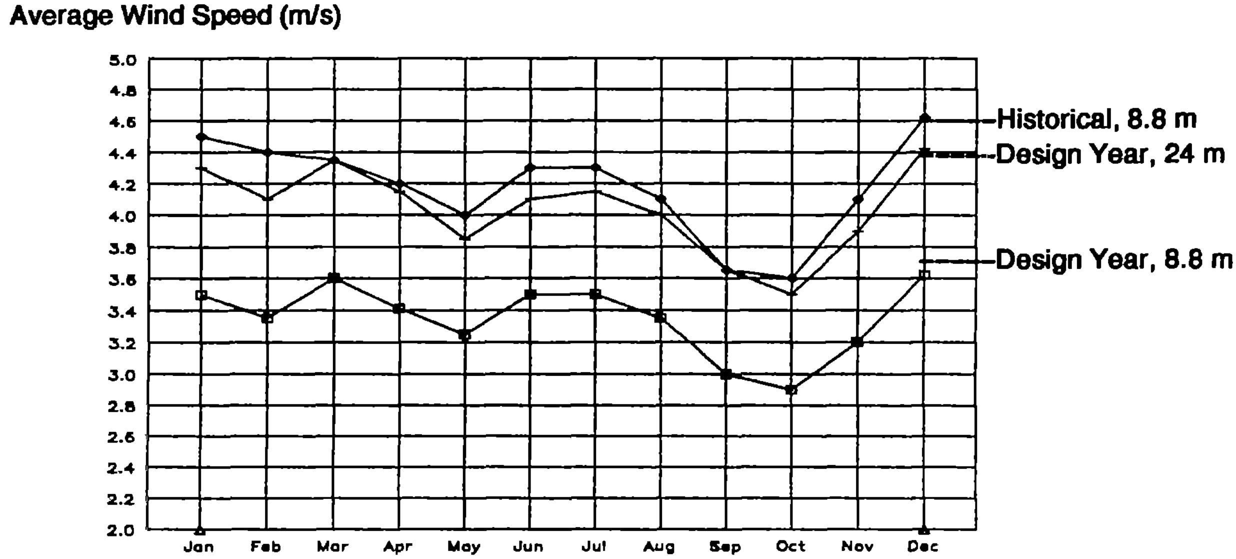
CDER has provided a detailed analysis of 37 years of wind data from the airport at Oujda. They have developed a "design year" wind regime in monthly average wind speeds by subtracting one standard deviation from the historical monthly average wind speeds. The "design year" annual average wind speed is 4.11 m/s and the low wind speed month is October at 3.6 m/s. Looking at inter-annual wind resource variations, the wind resource at Oujda should be higher than the "design year" regime 84% of the time. Using field tested flow curves (instantaneous flow rate vs. wind speed) for the two configurations and CDER's "design year" wind regime, BWC expects the EXCEL-PD's to provide approximately 105% of the target delivery for Ain Tolba and Dar El Hamra during the worst case wind speed month of October.

Description of System Components

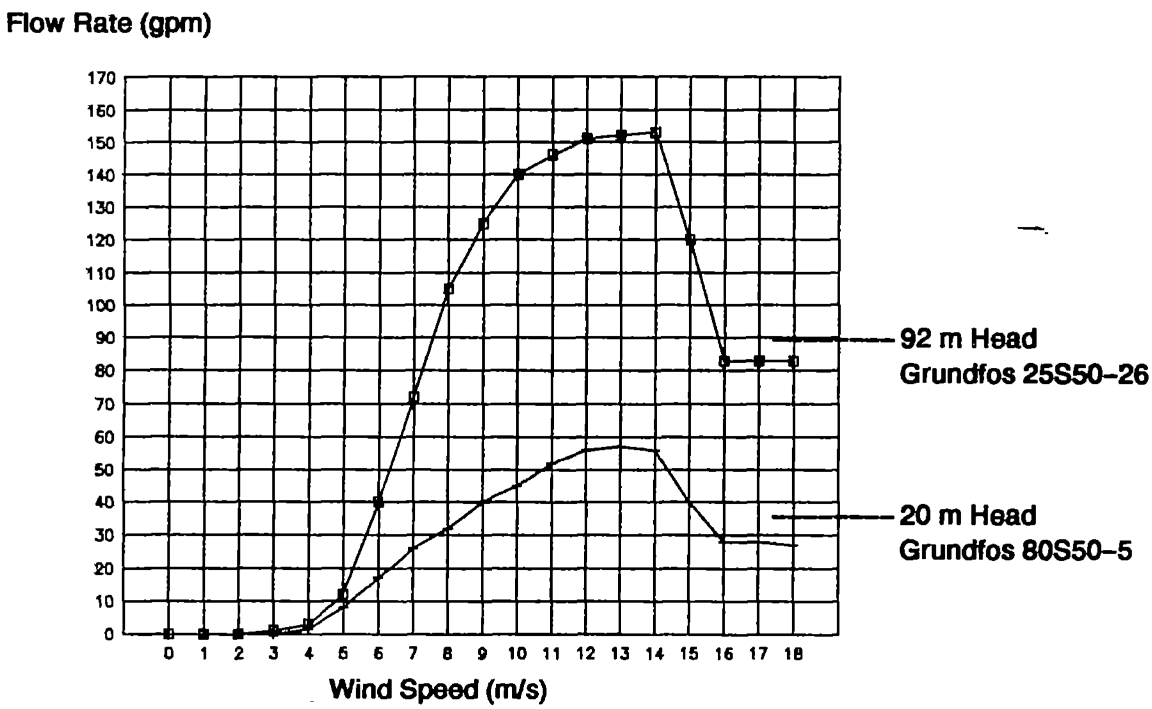
1. Wind Turbines

The wind turbines are Bergey Windpower BWC EXCEL-PD units rated at a nominal 10 kilowatts. The EXCEL is a three-blade upwind horizontal axis wind turbine with a rotor diameter of 7 meters (23ft). The rotor drives an alternator that produces a three-phase alternating current (AC) that varies in voltage and frequency with wind speed. This electrical output is used to drive the three-phase induction motors on the pumps at variable speed.

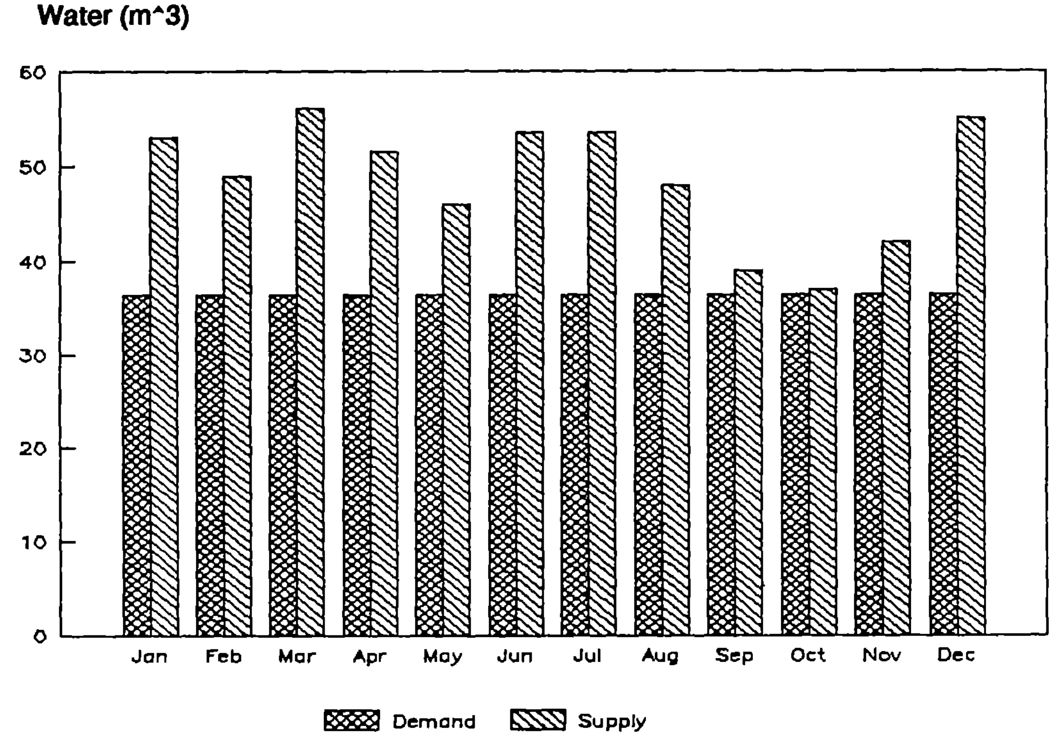
Historical and Design Wind Regimes
Naima Project



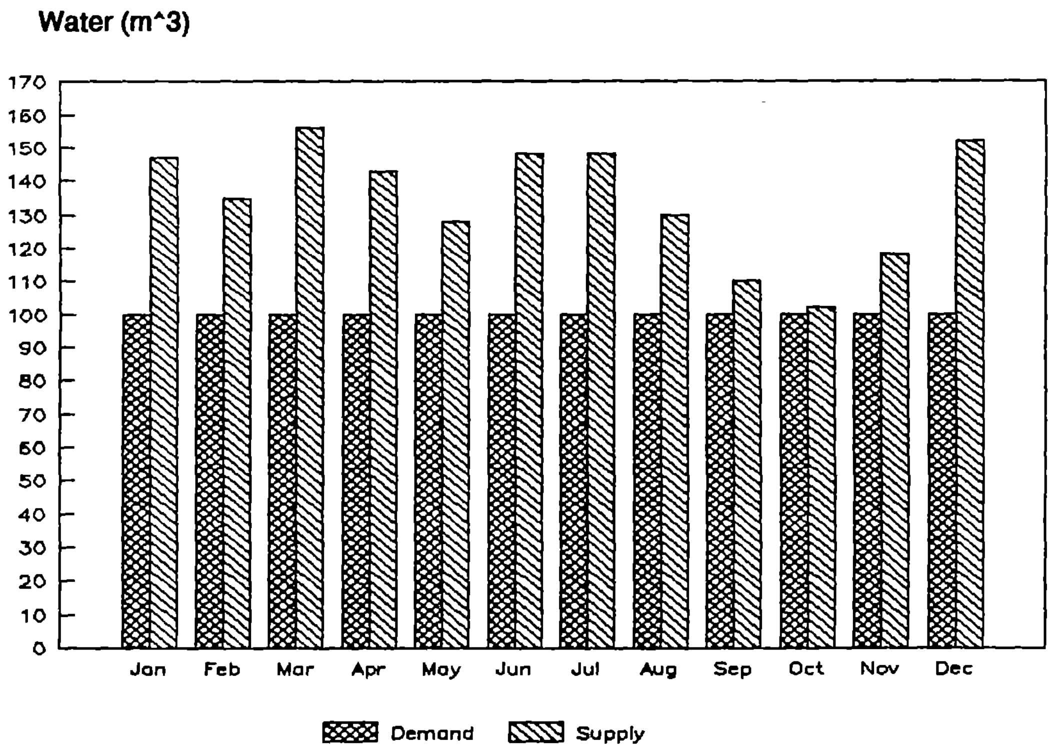
BWC EXCEL-PD Flow Curves
Naima Project



Daily Water Demand and Supply: Dar El Hamra - Design Year



Daily Water Demand and Supply: Ain Tolba - Design Year



Pump operation on the EXCEL-PD is controlled by the Pump Control Unit (PCU). The PCU is an electrical unit that provides monitoring of the system operational status and controls the electrical connection between the wind turbine and pump. As no power conditioning is required the PCU is basically a smart three-phase contractor. External sensors, a float switch and a pressure switch, are used to identify abnormal operating conditions and allow PCU shutdown of the system.

2. Towers

The tower is a 24.4 m. (80 ft.) Utility Tower Company type 340 guyed lattice tower with a guy radius of 12.2 m. The basic lattice element of the tower is a 20 ft. long section with a triangular cross section measuring 18 in. on a side. All lattice sections in the tower are composed of solid steel elements and the complete sections are hot-dip galvanized after fabrication. The tower has horizontal girts spaced 16 in. apart, so it is readily climbable. The tower is fitted with a anti-fall device for the protection of service personnel, has three sub-surface concrete anchors for the guy wires and two guy levels, one at the 32ft. elevation and another at 68 ft.

3. Pumps

Both systems use Grundfos multi-stage submersible pumps. The Ain Tolba system uses a five stage Grundfos 80S50-5 and the Dar El Hamra system uses a 26 stage 25S50-26. Both pumps are nominally rated at 5 hp (60 hz) but are fitted with 7.5 hp motors. The pump motors are 4 in. diameter, three phase, 230 VAC units. The motors and the pump ends are stock items. Each pump is fitted with a flow inducer housing to reduce heat build-up in the motors. The pumps are driven at variable speed directly by the wind turbine output. The output flow rate from the pumps is, therefore, dependent upon wind speed.

4. Water Delivery Monitoring Systems

The instantaneous flow rate and cumulative water delivery for each system in monitored with a Kent Series 3000 Turbine Flow Meter. These flow meters are placed between the pump and the connection point to the existing diesel pump piping, so that only the wind-powered pumping is monitored. Each of the Kent flow meters is also fitted with a remote electronic display specifically calibrated in metric units (liters/second and cubic meters).

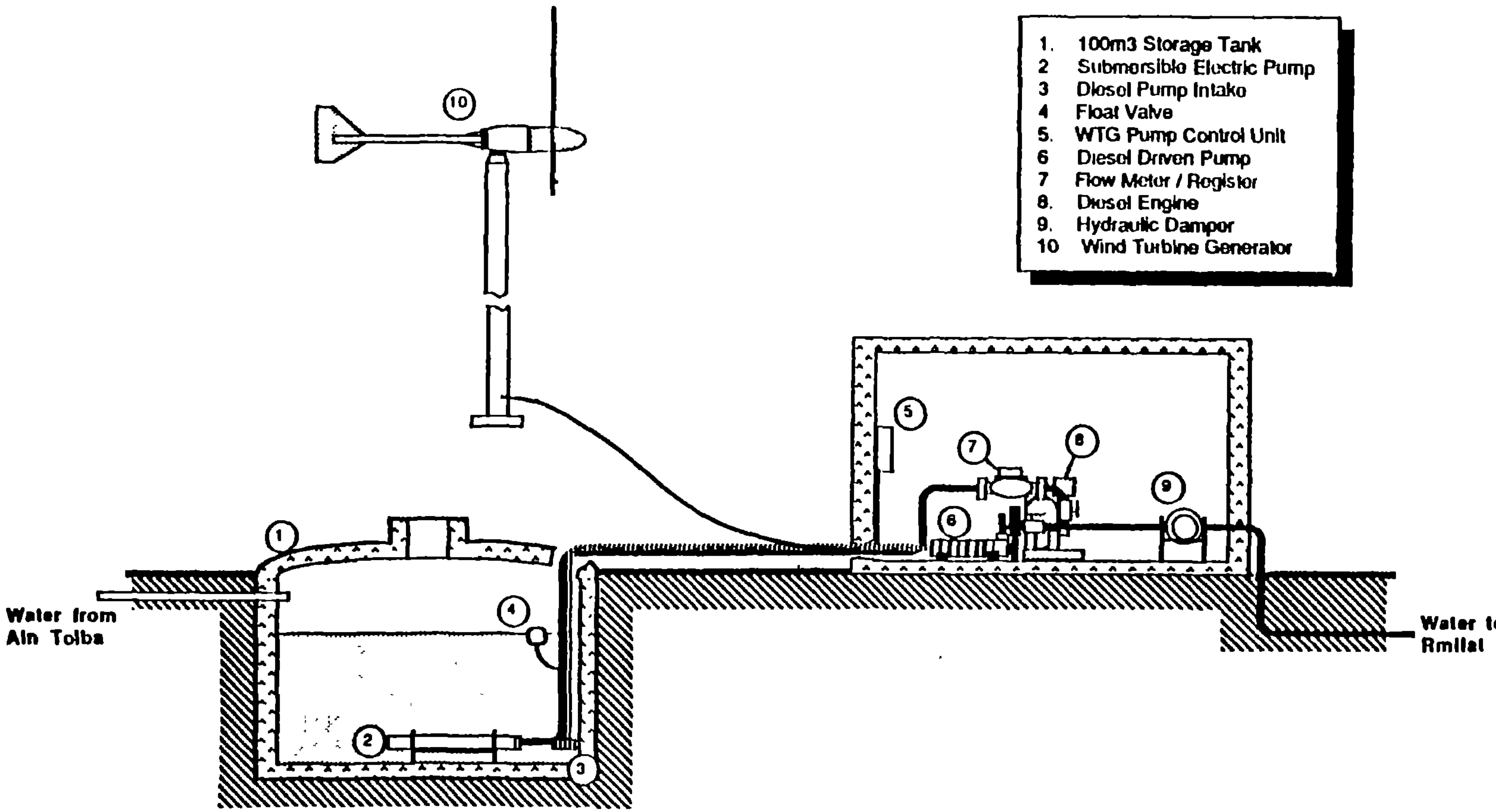
5. Power Production Monitoring Systems

A specially built AC kilowatt-hour meter is installed between the wind turbine and pump at each site. These KWH meters monitor cumulative energy production so that a measure of system efficiency can be obtained. The KWH units had to be specially built because they must monitor three phase AC, which varies in frequency from 0-120 hz.

6. Wind Characteristics Monitoring Systems

Each site is fitted with a Second Wind AL2000-S wind monitoring system, with its sensors installed on an 80 ft. NRG Tall Tower instrumentation mast. The Second Wind AL2000-S records wind speed histograms, wind roses, lull durations, and hourly average wind speeds. This information will allow detailed performance analyses to be made of the EXCEL-PD systems. The NRG Tall Tower places the anemometers and wind direction sensors at the turbine hub height, which negates the need for making shear corrections.

Dar El Hamra Equipment Layout



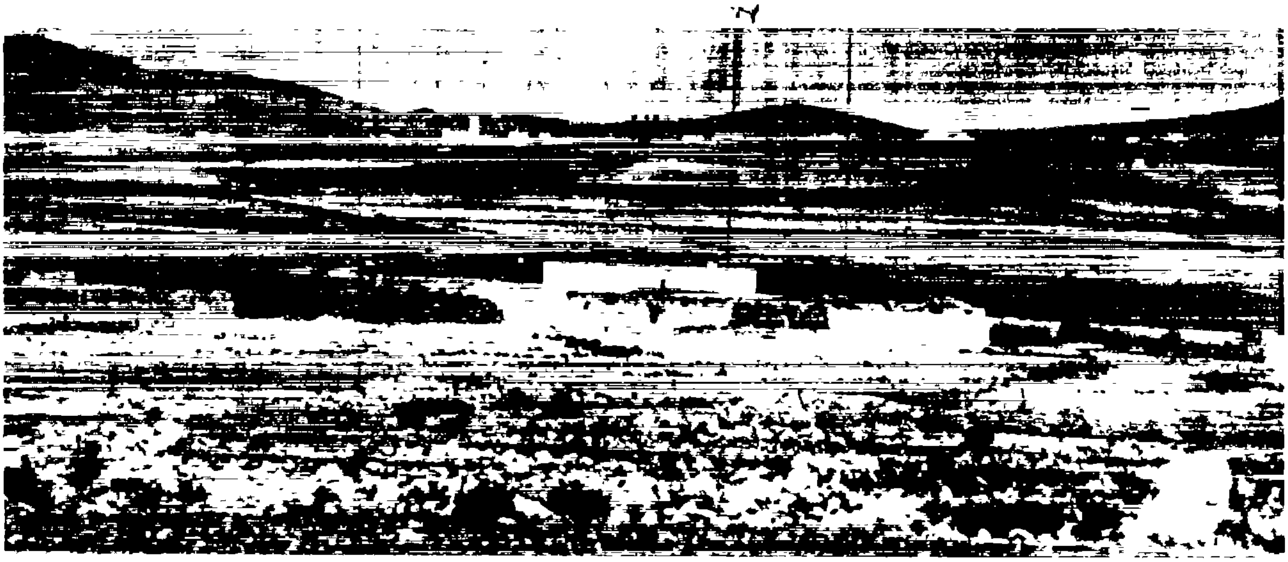
APPENDIX 2

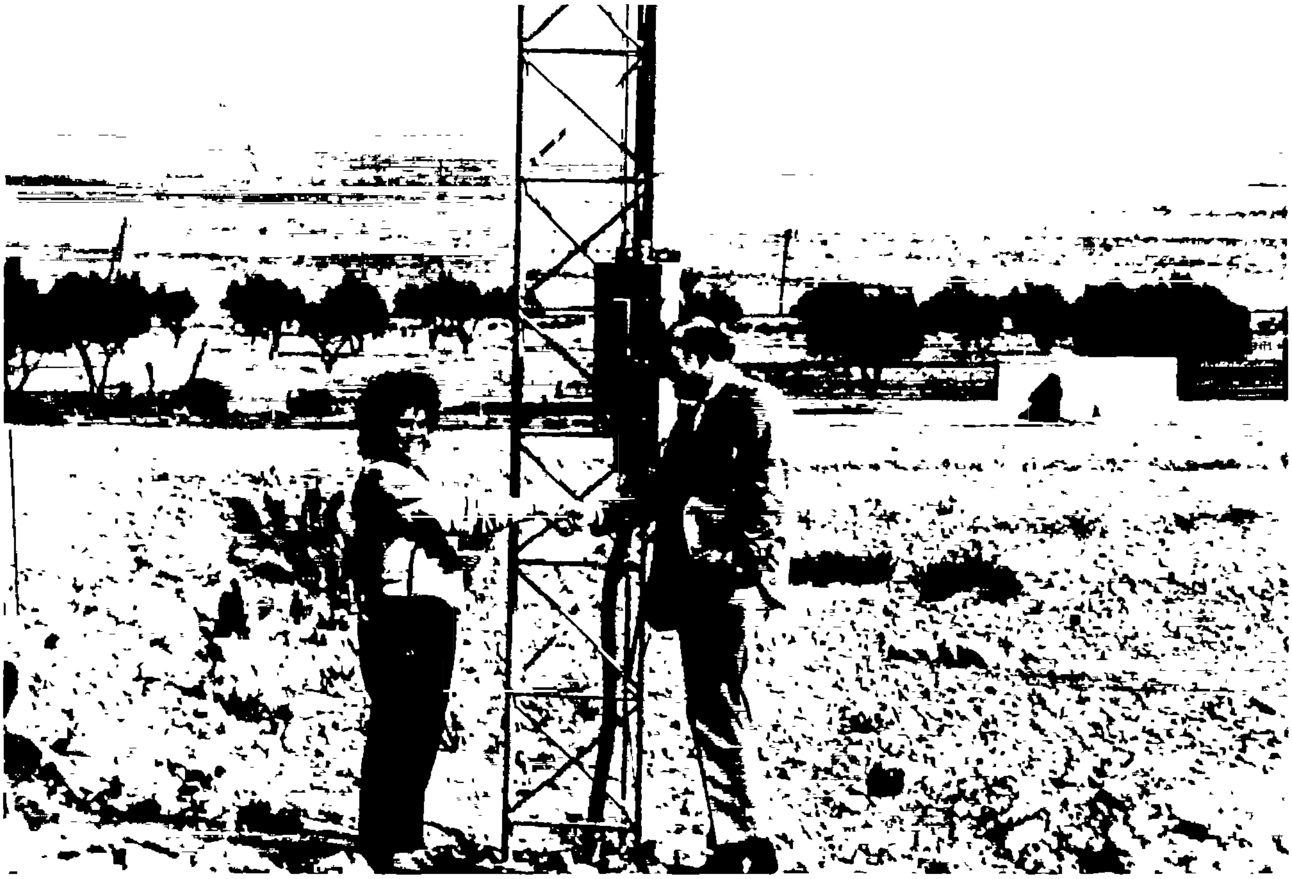
PICTURES OF THE NAIMA WIND PROJECT INSTALLATIONS

The first picture is of Ain Tolba, taken from the far bank of the Oued Isly. The picture shows the existing diesel pump building, the new $50m^3$ partially buried tank and the BWC wind turbine. The girls in the foreground are fetching water in recycled vegetable oil containers.

The second picture shows the Dar El Hamra installation in the foreground and the village of Rmilat in the right background.

The third picture shows the system at Dar El Hamra being unofficially accepted by Stephen Klein, the AID MREDP project manager, and Noura Kalai, the DPA/Oujda project manager. The water point can be seen in the background.





APPENDIX 3

Excerpt from the draft final report of the SERI supported project "Testing and Analysis of Small Wind Electric Water Pumping Systems (SWEPS)", M. L. S. Bergey, Bergey Windpower Co.

Excerpt from Draft Final Report

1. INTRODUCTION

1.1 Background

The availability of safe, reliable, and convenient drinking water is a key requirement for sustainable rural development. However, according to World Bank\UNDP estimates between 1.5 and 2 billion people do not have access to safe, uncontaminated water. In many undeveloped parts of the world people collect water from rainfall, surface sources or hand dug wells. These sources are easily contaminated, contributing substantially to rural health problems. As a result, according to the World Health Organization, 15 million children under the age of 15 die each year from diseases transmitted through contaminated drinking water. According to the U.S. Agency for International Development, 80 percent of all illness in developing countries is attributed to unsafe and inadequate water supplies and sanitation, and half the hospital beds are occupied by patients with water-related diseases.

Collecting drinking water can also be a significant drain on the human resources of rural populations. It is not uncommon for drinking water to be fetched on foot daily from distances up to 10 km (a task that falls mainly on women and children) or for many hours to be spent manually lifting water from hand-dug wells. The time spent in these activities lowers agricultural productivity and impedes education. Given the relatively modest amount of "power" available through manual labor, the amount of water that can be delivered with manual methods is quite limited. Animals are commonly used for fetching and lifting purposes, but even then the amount of water that can be delivered is limited by low "power" availability.

The installation of community water supply systems that tap clean subsurface water supplies are therefore a high priority for developing countries, donor organizations, and international funding agencies. The magnitude of the task of providing safe water is, however, daunting. In 1979 the World Bank and the United Nations Development Programme launched the multi-lateral International Drinking Water Supply and Sanitation Decade (IDWSSD) program to bring safe water to all of the worlds rural poor within ten years. But after ten years of focused effort, the WB\UNDP organizers have found that there are now more people without safe water than when the program began. Ground has been lost due to population growth, financial constraints arising from developing country debt, and shifting donor aid priorities. Clearly, greater efforts will be required in the future. The World Bank now estimates that the cost of meeting rural water supply needs to the year 2000 is in the range of $50-150 billion, depending upon the level of service provided. In most cases the main cost elements in providing new water supplies will be drilled wells and the equipment for pumping the water.

In some situations it is possible to construct a water supply system that is gravity fed because the water source is elevated in relation to the user's location. Rural water supply agencies tend to develop these resources first, as they are the easiest and least expensive. In most situations, however, a pumping system is required to lift and/or transport the water. Since the utility grid seldom extends into rural areas in need of water resource development, non-conventional pumping methods are necessary. The dominant pumping technologies in developing country rural areas are handpumps and diesel-powered pumps.

Handpumps are often chosen on the basis of their low first and operational costs, acceptable reliability, and local supportability. The output from handpumps, however, is limited by the low power input of manual labor and they are not effective for well depths greater than 40 meters. The main focus of the IDWSSD technical activities were in handpump technology. The use of diesel powered pumps is common in more developed rural areas for higher volume applications, but the high operating costs for these units generally constrains their utilization. In many less developed countries the availability of reliable fuel supplies and skilled maintenance services in rural areas can not be assured and even when they are, the equipment users often have difficulty generating the hard currency required for support. Pumping costs with diesels are also subject to significant economies of scale, making them very expensive on a per unit of water delivered basis at low demand levels. It is worth noting that European and Japanese companies are the leading exporters of handpumps and small diesels. A sizable market niche exists between the delivery range of the handpump and the economic viability range of small diesels, where other pumping technologies can provide lower pumping costs.

Water pumping/lifting systems powered by renewable resources, such as solar and wind, are attractive because of their low operational cost. This makes them more sustainable than diesel pumps. Photovoltaic (PV) powered water pumping systems have been used successfully in developing country installations up to 30 kW. It is estimated that over ten thousand PV pumping systems, generally under 1.5 kW each, have been installed in the last decade. PV systems are attractive because of the solar cells modularity and simplicity, and the wide availability of solar resources. At $9 - $30 per installed watt, however, PV pumping systems can only compete with diesel systems for very low demand applications. Interestingly, Cabraal has shown that PV pumping systems can be less expensive than handpumps, on a life-cycle basis, when the costs of constructing the well are taken into account. Although the PV pumping system is considerably more expensive than the handpump it is able to increase water delivery more than enough to justify its higher first cost.

Wind powered pumping systems can be very competitive with handpumps, PV systems, and diesels. It is estimated that over 12,000 mechanical water pumping windmills are installed worldwide each year. Nearly all of these windpumps are either direct descendants or local copies of the American multiblade windmill. It is a testament to the inherent value of the classic multiblade design that it can complete today even though the last major technical refinement was the advent of oil-bath gear lubrication in the 1920's. The use of mechanical windmills, however, is constrained by a limited product size range, siting requirements (the windmill must be installed directly over the well), the need for regular maintenance, and a largely undeserved reputation of unreliability.

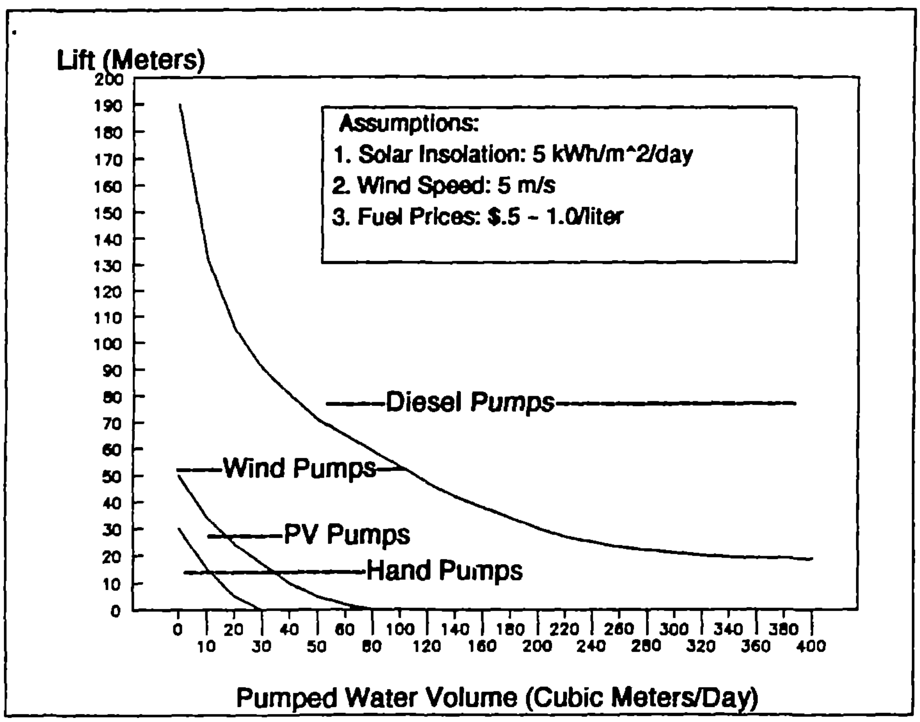


Figure 1. Range of Competitive Use of Water Pumping/Lifting Technologies

The competitive range of wind powered pumping systems can be seen in a least cost hierarchy of technologies plotted on a head-capacity chart, as shown in Figure 1. The regions defined for each water lifting/pumping technology represent the conditions of pumping lift and daily volume requirements under which the technology is the least expensive option, in terms of life cycle costs. The boundaries, which are highly dependent upon the assumptions used, are fourth-order curves defined by the daily energy requirement. Thus, it can be seen that handpumps are least expensive for low energy situations, followed by photovoltaic systems, windpumps, and finally diesels.

Wind electric water pumping is an emerging technology that offers the prospect of improving the competitiveness of windpumps by lowering the cost of water delivery, mitigating the disadvantages of conventional mechanical windpumps and opening new system design opportunities. It has the potential to expand the competitive range of windpumps and, thereby, increase the role of wind energy in providing safe drinking water to the worlds' poor.

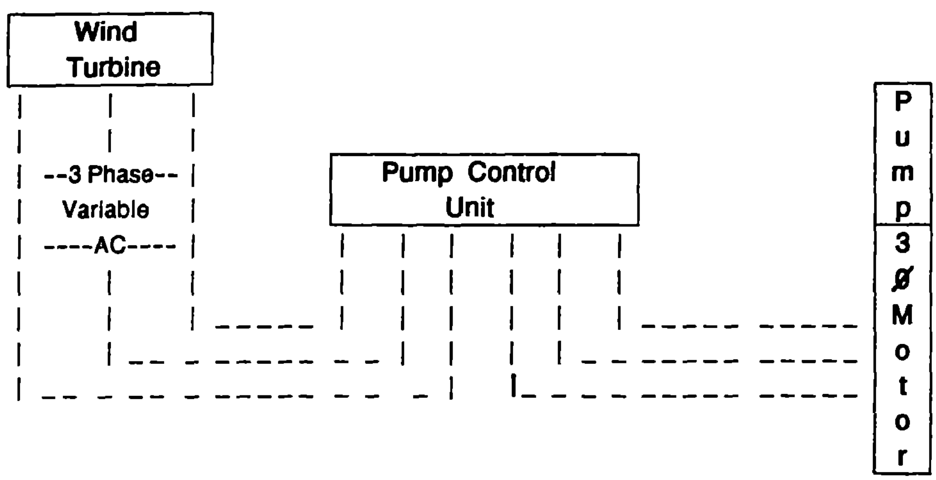


Figure 2. SWEPS Electrical Schematic

In a SWEPS (Small Wind Electric Pumping System) a high speed, low solidity wind turbine is connected electrically to a motor-driven centrifugal pump. The wind turbine operates at a variable speed and produces a variable voltage, variable frequency three-phase alternating current (AC) from its alternator. As shown in Figure 2., this output is directly connected to a three-phase induction motor that drives the pump. The pump operates at a variable speed which is determined by the wind speed. SWEPS do not require the batteries and static inverters used in conventional wind electric pumping systems.

Theoretically a SWEPS offers a number of advantages over a conventional mechanical windpump:

A. Higher Operating Efficiency

The rotor efficiency of a wind turbine can be 50% higher than that of the high solidity windmill rotor. The power matching between the rotor and the pump is also potentially better on the SWEPS. The power required by a windmills volumetric pump varies with the square of its speed, which does not correspond well with the cubic power available from the rotor (assuming a constant tip speed ratio). A centrifugal pump, on the other hand, has a power requirement that varies with the cube of its speed. The lower hydraulic efficiency of centrifugal pumps and the "electrical drivetrain" losses serve, however, to reduce the efficiency gains of the wind turbine rotor.

B. Siting Flexibility

A windmill must be sited directly over the well. This becomes a significant limitation in complex terrain because water resources tend to be down-slope and wind resources tend to be up-slope. It can also be quite awkward to install a windpump directly over the large diameter hand-dug wells common to developing countries. The SWEPS wind turbine can be installed at a great distance from its pump and the pumps could be easily retrofitted to existing wells. It is also possible to drive several smaller pumps with a single SWEPS.

C. Improved Reliability

Some small wind turbines have shown availabilities in the 98-100% range over extended periods with little or no scheduled maintenance. Centrifugal pumps do not require regular maintenance and are also quite reliable. Windpumps generally must be greased regularly and have their oil changed annually. The pump leathers on windmill pumps must be replaced every 12-24 months: a job that usually involves pulling up the entire pump casing string.

D. Rural Electrification Capability

Since the SWEPS produces electricity it would be relatively straightforward to tap part of the energy produced by the wind turbine for small electrical loads through a separate power conditioning and storage subsystem.

E. Larger Capacities

Mechanical windpumps are commercially available in diameters up to 25 ft., but even the largest units have maximum power outputs of only a few kilowatts. This is because the efficiency of mechanical windpumps peaks at low wind speeds and falls off dramatically at higher wind speeds. SWEPS units can use commercially available SWECS in the 1-100 kW range, so long as they are capable of autonomous operation. Even larger sizes are theoretically possible. This allows the SWEPS to displace diesel pumps over a much larger range.

In addition to its potential role in potable water supply, SWEPS may also provide significant benefits for agricultural and land management activities domestically and overseas. In the U.S. there is a growing need for irrigation and farming practices that are more energy and water efficient. According to figures compiled by West Texas State University there are some 510,000 low volume irrigators relying on electricity and natural gas in the southern Great Plains alone. As the cost of electricity and natural gas increase, the economic viability of these small farms could be affected.

At the beginning of the current BWC/DOE cooperative project the analytical and testing work of SWEPS; by the Brace Research Institute, Vosper and Clark, CWD, Bergey Windpower and others; had been sufficient to show the promise of the technology, but not sufficient to put an actual product on the market. The field testing done had been minimal and confined to the less difficult low head situation. Previous experimental work had also be restricted to a relatively narrow frequency range, typically 45-65 hertz. Some researchers had speculated that SWEPS would not be able to use standard wind turbines, pumps, or motors; that the efficiencies would be poor; and that SWEPS would only be able to operate over a narrow range of wind speeds. No analytical methods existed to size components and predict performance. The operations envelopes, practical engineering constraints, and control strategies of SWEPS had yet to be investigated. In short, SWEPS were a long way from commercialization.

1.2 Project Objectives

Wind Electric water pumping systems will be commercially viable only if they offer advantages in costs of water delivery, reliability, or design flexibility over alternative water pumping/lifting technologies such as diesels, photovoltaics, or mechanical windpumps. In order to deliver these advantages, SWECS designers must be able to optimize SWEPS performance based upon an understanding of the behavior and interaction of the various components that make up a wind electric water pumping systems. The overall objectives of the Testing and Analysis of Small Wind Electric Pumping Systems (SWEPS) program were therefore to quantify performance, to provide applications engineering guidelines and to develop design tools that would help achieve optimal system design.

The current project had four main sub-objectives:

- To provide detailed applications engineering information on the design and use of SWEPS.
- To design and test a series of SWEPS covering low head (H<10m), medium head (10<H<80m) and high head (H>80m) applications.
- To develop an analytical model of the SWEPS.
- To perform a technology assessment of SWEPS in a developing country context.

An additional aspect to the project was introduced in mid-1987 when Bergey Windpower received a contract to supply two 10kW SWEPS for a USAID sponsored village water supply project in rural northeast Morocco. As these systems would be first-of-a-kind units, BWC proposed that the systems be field tested in the U.S. prior to shipment to Morocco. Since the Morocco sites had total dynamic heads of 20m and 93m, SERI kindly agreed to allow the pumps selected for Morocco to be tested as the medium and high head pumps under the current project.

The connection between the DOE\SERI and USAID projects turned our to be highly symbiotic. It provided a real world focus to the applications engineering and technology assessment components of the DOE\SERI project. Field testing of SWEPS in turn revealed major operational problems with the pumps originally selected for Morocco. The systems ultimately installed in Morocco (April, 1989) were second generation designs and by then well tested in the U.S. field trials. If the systems in Morocco prove to be successful, much of the credit for the success will be attributable to the insights gained in the DOE\SERI project.

APPENDIX 4

Technical paper presented at the 1990 Annual Conference of the American Wind Energy Association

SUSTAINABLE COMMUNITY WATER SUPPLY: A CASE STUDY FROM MOROCCO

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AWEA National Conference, September 1990

The following is an excerpt from a paper presented at the American Wind Energy Association (AWEA) National Conference of September 1990. Rather than present the entire paper, only those sections providing additional information to that already included in this report are reproduced here.

Recent Operating Experience

During the February 1990 mission, acceptance testing for the wind equipment was performed by BWC and CDER staff. The BWC supplied pumping systems were required to demonstrate performance at least 80% of that specified in the tender. Since the actual dynamic pumping heads at the two sites turned out to be over 20% higher than specified, however, the performance requirements were correspondingly reduced. As can be seen in the attached graphs, the acceptance testing showed that the equipment met the specified performance requirements and, in fact, showed less derating for the higher head than would be expected. The higher dynamic heads did increase cut-in wind speeds (minimum wind speed required to initiate pumping) about 1-2 m/s, which has the adverse effects of reducing pumping operating time and increasing the hydraulic hammer affect at cut-in.

Some operational problems were experienced in March when high winds tripped underrated lightning surge arrestors, causing both systems to be down for nineteen days while replacement parts were shipped from the U.S. Other than this interruption the operation of the systems has been satisfactory. The equipment has now been turned over to the local DPA and is being monitored and maintained by a BWC trained local business, Spolyten S.A. of Oujda. Communications and cultural understanding have been greatly improved through the services of a Moroccan graduate student at the University of Oklahoma, located in Norman, who now provides liaison between BWC and Spolyten.

The following summaries cover performance through September 20, 1990:

Ain Tolba

Since April 3rd, the date the surge arrestor problem was corrected, the wind pumping system at Ain Tolba has been 100% available. This put the cumulative availability at 91.2% since the system was recommissioned in February. Since that time over 3.7 million gallons of water have been pumped. The average daily volume of 17,470 gallons (66.2m^3) is 100.2% of the performance target specified by CDER and corrected for the higher head. This figure includes the nineteen days downtime in March. The daily water volume has increased 220% over that previously pumped by the diesel. The diesel pump has not had to operate since the repairs were made on April 3rd.

Dar El Hamra

At Dar El Hamra, the wind pump system has been approximately 97% available since April 3rd due to thermal breaker trips. This put the cumulative system availability at 88.8% since the system was recommissioned in February. Cumulative pumped volume is not available for Dar El Hamra due to a problem with flow metering, but DPA/Oujda reports that sufficient water has been supplied to Rmilat since April.

Thus the systems seen to be performing as intended and have carried the Commune users through the dry season. The project has also spawned non-subsidized commercial sales of wind electric pumping systems in Morocco and neighboring countries. Current projections of the market development indicate that local production of BWC wind turbines in Morocco may be justifiable within a few years. While it is far too early to make broad claims about the reliability and O&M costs of wind electric pumping systems the experience to date is sufficient to show that the potential for a more sustainable community water supply option. The Naima Wind Project also show that development assistance projects, if properly crafted, can be effective in introducing more sustainable water supply options in developing countries.

Economics

The Naima Wind Project cost approximately $120,000, but this cost includes a number of non-recurring cost items and extensive instrumentation. The replication cost for each of the 10 kW systems, excluding any storage tank construction required, is approximately $25,000 or $2.50/watt installed. Local production of towers and eventually the wind turbine could lower this cost by as much as 40%.

A thorough treatment of the economics of WEPS in Morocco is well beyond the scope of this paper. As part of the SERI supported research, Alan Wyatt of Research Triangle Institute has produced an extensive analyses [Ref.: "Technology Assessment,..."] of the economics of WEPS in Morocco and its relative competitiveness with other pumping technologies such as diesels, photovoltaics, conventional windpumps, and advanced windpumps (such as the models promoted by CWD). The results show that WEPS in the range of 3-7 m rotor diameters (the range evaluated by Wyatt) offer the least cost approach on a life-cycle cost basis in most situations where the wind resource is 3 m/s or greater. This resource is available over the vast majority of Morocco. The analysis also shows that WEPS is the first renewable energy technology to be competitive in pumping volume and life cycle economics with the 8-12 hp diesel pumps commonly used for community water supply.

Lessons Learned

The Naima Wind Project has yielded a number of valuable lessons. Chief among them are the following:

1. Wind electric water pumping is an appropriate technology for sustainable community water supply.
2. Public/private cooperative technology development can be very effective if it has a clear commercial goal.
3. Development assistance programs can play an important catalytic role in transferring technology.
4. Project planners and contractors must take a realistic and rigorous approach to operational support.

Predicted and Tested Performance at Ain Tolba

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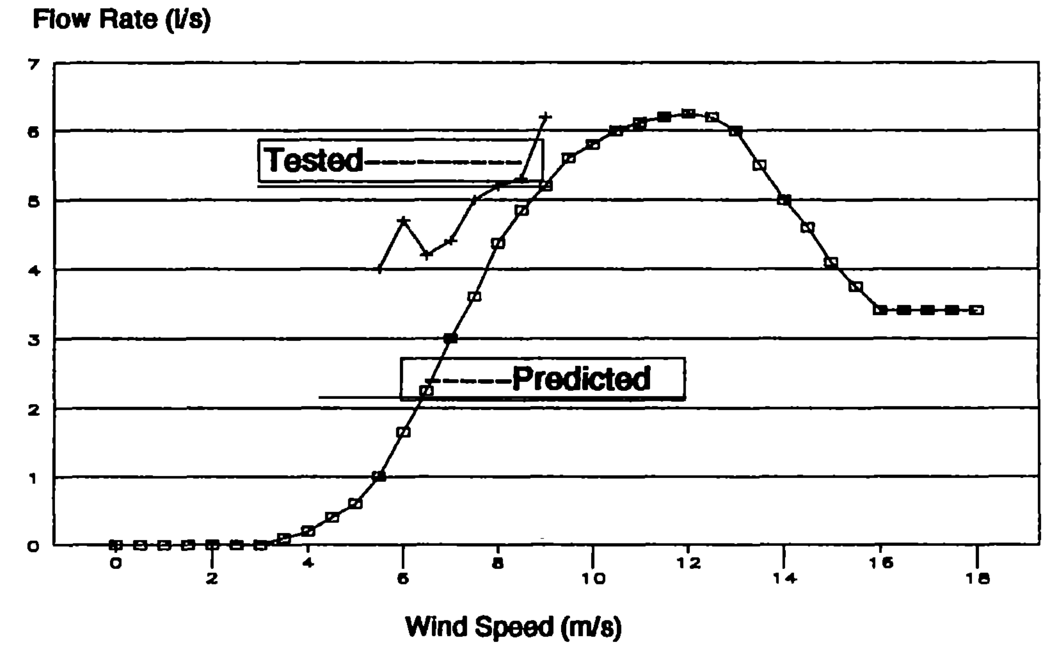
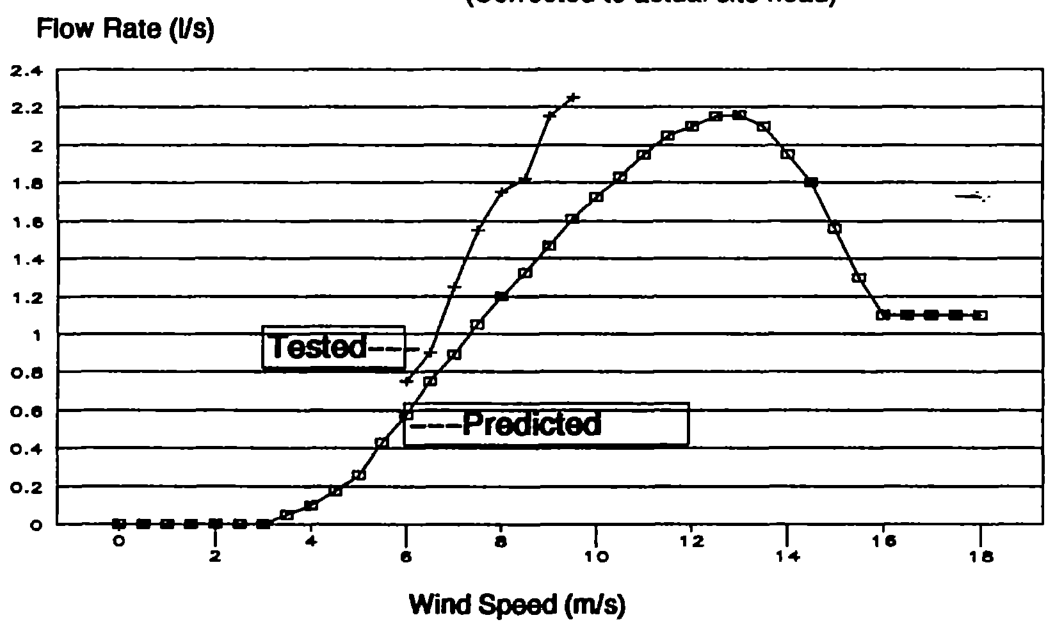


Predicted and Tested Performance at Dar El Hamra

(Corrected to actual site head)



The A.I.D. Office of Energy and Infrastructure

The Agency for International Development's Office of Energy and Infrastructure plays an increasingly important role in providing innovative approaches to solving the continuing energy crisis in developing countries. Three problems drive the Office's assistance programs: 1) high rates of energy and economic growth accompanied by a lack of energy, especially power in rural areas; 2) severe financial problems, including a lack of investment capital (especially in the electricity sector); and 3) growing environmental threats, including urban air pollution, acid rain, and global climate change.

To address these problems, the Office of Energy and Infrastructure leverages financial resources of multilateral development banks, the private sector, and bilateral donors to increase energy efficiency and expand energy supplies, enhance the role of private power generation, and implement novel approaches through research, adaptation, and innovation. These approaches include improving power sector planning ("least-cost" planning) and encouraging the application of cleaner technologies that use both conventional fossil fuels and renewable energy sources. Promotion of greater private sector participation int he power sector and a wide-ranging training program to help build the institutional infrastructure necessary to sustain cost-effective, reliable, and environmentally-sound energy systems integral to broad-based economic growth.

Much of the Office's strategic focus has anticipated and supports recently enacted U.S. congressional legislation directing the Office and A.I.D. to undertake a "Global Warming Initiative" to mitigate the increasing contribution of key developing countries to greenhouse gas emissions. This initiative includes expanding least-cost planning activities to incorporate additional countries and environmental concerns, increasing support for feasibility studies in renewable and cleaner fossil energy technologies that focus on site-specific commercial applications, launching a multilateral global energy efficiency initiative, and improving the training of host-country nationals and overseas A.I.D. staff in the areas of energy that can help to reduce expected global warming and their environmental problems.

To pursue these activities, the Office of Energy and Infrastructure implements the following seven projects: 1) the Energy Policy Development and Conservation Project (EPDAC); 2) the Biomass Energy Systems and Technology Project (BEST); 3) the Renewable Energy Applications and Training Project (REAT); 4) the Private Sector Energy Development Project (PSED); 5) the Energy Training Project (ETP); 6) the Conventional Energy Technical Assistance Project (CETA); and 7) the CETA follow-on Energy Technology Innovation Project (ETIP).

The Office of Energy helps set energy policy direction for the Agency, making its projects available to meet generic needs (such as training), and responding to short-term needs of A.I.D.'s field missions in assisted countries.

Further information regarding the Office's projects and activities is available in our annual Program Plan, which may be requested by contacting:

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