

*Dissemination of the
Nicaraguan Rope Wind pump Technology to
Latin American countries
Final Report on Evaluation & Transfer of Technology*

J.A. de Jongh & R.P.P. Rijs (editors)

RED Renewable Energy Development
Eindhoven, The Netherlands

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The underlying report presents the results of a project to evaluate and disseminate the technology of the rope and washer windpump as developed during the last decade in Nicaragua. The project has been initiated by the non-governmental organisation CESADE, Managua and the overall project manager was RED vof, Eindhoven, the Netherlands.

The project has been financed by the Royal Embassy of the Netherlands in Managua under the name "Windmolen-touwpomp evaluatie" with activity number NI 013002 (NI 013001). The terms of the project have been defined in the document "Dissemination of the Nicaraguan Rope Windpump Technology to Latin American Countries (second version, November 1997). The activities under this project are executed under responsibility of RED vof, the Netherlands, and CESADE. Nicaragua, which both have engaged into a contract with the Embassy.

LIST OF ABBREVIATIONS

AMEC	Aerobombas de Mecate S.A. de C.V.
CESADE	Centro de Estudios y Acción para el Desarrollo
CICUTEC	Centro de Intercambio Cultural y Técnico
CITA-INRA	Centro de Investigaciones en Tecnología Apropriada - Instituto Nicaragüense de Reforma Agraria
COSUDE	Swiss Cooperation for Development
CWD	Consultancy Services for Wind Energy in Developing Countries
DOG	Dienst over Grenzen
DAR	Dirección de Acueductos Rurales
IMEP	Industrias Metalúrgicas del Pueblo
INAA	Instituto Nicaragüense de Acueductos y Alcantarillados
IRC	International Water and Sanitation Center
INTA	Instituto Nicaragüense de Tecnología Agropecuaria
MIDINRA	Ministry of Agriculture and Agrarian Reform
PASOC	Programa de Agua, Saneamiento y Organización Comunitaria
RED	Renewable Energy Development vof
SNV	Stichting Nederlandse Vrijwilligers
UNI	Universidad Nacional de Ingeniería

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SUMMARY

The present document describes the results of a project to evaluate and transfer the Nicaraguan rope windpump to Latin America. The project consisted of three phases: an evaluation on technical, social and economic aspects; a presentation of the results; and a first transfer of the technology to Latin America. The project was financed by the *Royal Embassy of the Netherlands* in Managua and executed by RED vof (the Netherlands) and *CESADE* (Nicaragua) as main contractors. Other collaborators were *Gamos Ltd* (UK); *ERA* (Costa Rica); *CICUTEC*; the *Universidad Nacional de Ingeniería*; and workshop *AMEC* (Nicaragua).

The evaluation was based upon a mission to Nicaragua; an end-use survey and a technical measuring programme. The main objective was to draw conclusions on the current status of the windpump in Nicaragua and give recommendations regarding technical improvements and a subsequent transfer. The results were presented during a national workshop in Managua for farmers and institutions involved in rural development, and an international workshop for potential manufacturers and development organisations in Latin America. From September 1998 to February 1999, the rope windpump was transferred to four countries: Peru, Bolivia, Guatemala and Cuba.

The concept of the rope windpump avoids a number of typical, technical problems encountered in classical windpumps. The resulting lightweight windpump has a remarkably high water output, but also needs daily attention for operation and maintenance. However, the evaluation showed that this is easily done by most users. The production of the windpump during the transfers involved several modifications to cope with locally available materials, but this never caused a significant delay. Apparently, the rope windpump can be adapted quickly to local conditions, which is an important asset for dissemination and sustainability outside Nicaragua.

The initial investment of about US\$ 800,- (in Nicaragua) may be up to 6 times lower compared to a classical windpump. With its low recurrent costs, it is an attractive alternative to other technologies. A first analysis of the economy for cattle watering reveals a unit water cost of approx. US\$ 0.14,- per m³ (pumping head 20 m). Currently, about half of all rope wind pumps are used for cattle water supply on a commercial basis.

The low costs open the perspective of profitable small-scale irrigation for the sector of small farmers in Nicaragua and abroad, for whom the high initial investment of other pumping technologies is usually prohibitive. A preliminary cost-and-benefit analysis reveals a possible income increase of about 30%. A more accurate estimate may be given, once more detailed data has become available about small-scale irrigation practices by this group of users, which by now is still a developing activity.

The current standard model has been designed specifically for the trade wind regime prevailing in Nicaragua. The applied transmission system limits the functionality in regions with a variable wind direction. *AMEC's multigratorio* is a first step towards a more versatile system, but is still under development.

The Nicaraguan rope windpump deserves further promotion and support. In fact it is the concept of the rope pump that can be combined with a range of traction methods, which should be promoted. Its flexibility makes it likely to devise a system that will match with a local need for water for different

groups of users and under varying conditions. In this view, the rope windpump is a valuable system that may be applied for pumping larger water volumes. If more people become involved in the development and promotion of the rope pump technology, it is expected that adequate pumping solutions are found more quickly and the existing rope windpump models will further mature.

COMPARISON OF ROPE WINDPUMP WITH OTHER TECHNOLOGIES			
	Diesel-electric Pump	Classical Windpump Chicago Aermotor	Rope Windpump H-12 Model
<i>Supply of capital equipment</i>			
Manufactured in Nicaragua			•
Produced with local materials			•
Produced using basic machinery			•
System "off the shelf" available within Nicaragua			•
Lifetime (years)	6	20	12
Water Tank required (lifetime 30 yrs)	•	•	•
<i>Installation and maintenance</i>			
Installed by supplier (if required)	•	•	•
Pump maintenance possible by user			•
Repairs possible by local craftsman			•
Spares readily available in Nicaragua			•
Not vulnerable to import restrictions			•
<i>Performance</i>			
Able to pump up to...m	80 +	80	50
Includes back-up system		•	•
Difficult to steal		•	•
Possible other uses (eg battery charging)	•		•
Runs unsupervised		•	
<i>Example economics in Nicaragua</i>			
Type of application	Cattle watering	Cattle watering	Cattle watering
No of cattle	200	200	200
Water requirement/day	8 m ³	8 m ³	8 m ³
Assumed head	20 m	20 m	20 m
Capital cost	US\$ 2,400,-	US\$ 5,000,-	US\$ 800,-
Water tank	US\$ 150,- (8 m ³)	US\$ 500,- (34 m ³)	US\$ 500,- (34 m ³)
Installation, transport, civil works	US\$ 450,-	US\$ 450,-	US\$ 110,-
Maintenance costs	US\$ 150,-	US\$ 300,-	US\$ 50,-
Fuel costs	US\$ 60,-	-	-
Operator costs	US\$ 90,-	-	US\$ 180,-
Annualised Life-Cycle Costs (20 years)	US\$/m ³ 0.0150	US\$/m ³ 0.0171	US\$/m ³ 0.0073
Cost per m ³	US\$ 0.30	US\$ 0.34	US\$ 0.14

Comparison of alternative pumping technologies for cattle watering in Nicaragua

PART A:
CONTEXT, METHODOLOGY
AND OBJECTIVES

1. INTRODUCTION

A reliable and safe supply of clean water is perhaps the most basic need for human subsistence. It is indispensable for personal hygiene and health, and a key factor for food production and development in rural areas. Access to clean water relies very much upon the sustainability of the water supply systems. Often sustainability is neglected by project planners. It is a common experience that handpumps break down after a few years of operation and that engine-powered water pumps stop functioning because spare parts are not available or fuel supply is not guaranteed. There is a growing awareness that user-involvement in the choice of a technology and maintenance and operation is a crucial factor for sustainability.

The Nicaraguan rope windpump or "aerobomba de mecate" was developed from the experiences gained in a wind energy project financed by the Dutch government in the late 1980's. It was found that the existing "classical" and "modern" windpumps were too expensive and too complex for the local market. This in turn caused problems in production, installation and maintenance.

Some of the advisors involved in this project decided to develop a new low-cost windpump. It was considered acceptable that a "low-cost" windpump would need more maintenance, if the user could do this. In the long term this would lead to a cheaper and more sustainable solution. The resulting concept incorporated a rope pump based on the "bomba de mecate" hand pump that was becoming very popular in Nicaragua at that time.

The rope handpump has a number of features that have formed the basis for its success in Central America. Some years ago, it was extensively evaluated by the International Water and Sanitation Centre in the Netherlands [1]. In this report, the combination of a rope pump and a windmill was identified as a potentially interesting pumping system, and it was recommended to evaluate this combination on its merits and potential.

The rope windpump or "Aerobomba de Mecate" builds forth on the technological concept of the rope handpump. It is a simpler device than the conventional piston pump, which is normally used for windpumping. The technology of the rope windpump is thus more easily understood by the user, and the system can be produced locally. Daily attention and maintenance by the user is needed and possibly the performance is somewhat lower, however the overall costs are low.

The high investment costs for sophisticated, imported devices are prohibitive for most of the poor families of the rural population. The introduction of these low-cost technologies provides them with a service that would otherwise remain out of reach.

The strong points of the rope handpump have contributed to its broad social acceptance in Nicaragua. At present more than 13,000 of these handpumps are installed in Nicaragua where it is the cheapest handpump available. The major market for rope pumps in Nicaragua is for family use, where it is mostly operated --and often maintained-- by women and children. Larger versions of the rope pump are in use for communal wells, cattle watering and small-scale irrigation.

The rope windpump as yet cannot boast such a history: in 1998 about one hundred units had been installed in the country. However, the designers -manufacturer AMEC and the supporting organisation CESADE- have high expectations of the windpump, which has also drawn the attention in other countries in the region.

In 1997, after six years of development and implementation of this low-cost windpump in Nicaragua, CESADE considered it worthwhile exploring its potential for dissemination of to other countries in Latin America. The strategy would be to carry out a stepwise transfer of the technology, after an

independent evaluation of its technical, social and economic merits. A positive evaluation result would strengthen the basis for a successful dissemination.

The present document is the final report of the project "Dissemination of the Nicaraguan Rope Windpump Technology to Latin American countries". It is structured according the three major phases of the project:

- Phase I: The evaluation of the Nicaraguan rope windpump. The evaluation covers technical, social and economic aspects. Input information has been obtained from a field survey, an expert mission and a technical measuring programme.
- Phase II: The dissemination of the results of the evaluation. This has been done at two workshops in Managua, one for a national audience, the other for people from Latin American countries with a serious interest in producing and promoting the windpump in their home country.
- Phase III: The transfer of the technology. This concerns the transfer of the windpump technology to four selected manufacturers from different countries in Central and South America. The transfer includes drawings, manuals, local production, assembly and installation of a prototype, and training with input from CESADE and the Nicaraguan windpump manufacturer (AMEC).

The underlying report summarises the main findings of the three project phases. Part A of this report gives an outline of the methodology and objectives as a general introduction to the whole project, and a chronological summary of the activities to date. Part B describes the findings of the evaluation of the rope windpump and the results of the first transfers, concluding with recommendations regarding the technology, implementation strategy, and dissemination in the region.

The following documents elaborated by RED Renewable Energy Development vof contain additional information on various aspects of the evaluation and were used to draft this evaluation report:

- | | |
|---|--------------|
| • Preparation Measuring Programme (in Spanish) | PR-98-02-II |
| • Findings of the End-use Survey (in Spanish) | PR-98-02-III |
| • Results of the Measuring Programme (in Spanish) | PR-98-02-IV |

CESADE has prepared a number of documents for the Embassy in Managua, which are listed in the bibliography at the end of the report.

2. PROJECT OBJECTIVES

2.1 General Objectives

The general objectives for the project are circumscribed as follows:

- To increase rural production through the introduction of a low cost water pumping system in Latin American countries.
- The objective of this project is the evaluation and dissemination of the rope windpump to manufacturers and other interested parties in Latin America.

2.2 Specific Objectives

The objectives of the project are as follows:

- To evaluate the rope wind pump technology on its technical merits and economic and socio-cultural value for Nicaragua.
- To investigate the acceptance of the technology compared to other low cost windpump types available in the region.
- To draw conclusions with respect to the potential of the rope windpump technology for dissemination to other countries in the region.
- To build up human resources capacity on small scale wind energy technology in the region (by involving experts from countries in the region).
- To disseminate the outcomes of the evaluation and create interest among potential future manufacturers in the region.
- To start with the transfer of the technology to four (4) selected, interested manufacturers in Central and South America.

3. BENEFICIARIES

The beneficiaries of the project are identified as:

- On the long term: the farmers and rural families who may expect higher productivity and/or better access to water for domestic purposes.
- On the short and long term: the manufacturers, institutions, organisations and local experts active in the field of wind energy in Latin America.

4. PROJECT METHODOLOGY

The project is executed in three phases that follow one after the other:

- Phase I: Evaluation.
- Phase II: Dissemination of results.
- Phase III: Transfer of technology.

4.1 Phase I: Evaluation

The first project phase focuses on an evaluation of the rope windpump technology and the existing models in Nicaragua. The methodology and recommendations of the evaluation of the rope handpump by the IRC [1] were taken as a guideline for this report.

Four major activities were scheduled for the evaluation:

- a desk study

- an evaluation mission in Nicaragua
- an end-use survey
- a technical measuring programme

The desk study reviewed the history of windpumping in Nicaragua and Latin America. In addition, it was used to collect information about a number of social and economic issues related to the rural areas of Nicaragua and the role of water supply. This study was performed in the preparatory phase of the project (March 1998).

The evaluation mission focused on technical aspects such as design and construction, production methods, profile and organisation of the workshop, production costs, and so on. A number of rope windpump units in the field were visited. The evaluation mission took place from Monday 23 March until 4 April.

The end-use survey consisted of visits to rope windpumps installed in the field and was expected to reveal information about reliability, user (dis)satisfaction, operation, acceptance, and benefits. The survey was guided by a questionnaire and started on 25 March. It was completed on 16 April, with a break during *Semana Santa*.

The measuring programme was scheduled to determine the technical performance, availability and water production in relation to the wind speed. It was divided in a series of "short" term and "long" term measurements; the first measurements were done from 24-28 March; the start of the "long-term" programme was hampered by the absence of wind during the first half of April; in agreement with the Embassy, it was decided to extend the measurements, which were finalised at 18 July. According to the project proposal, the long-term measurements would cover a period in both the wet and the dry season.

The main goal of the first project phase has been to draw conclusions on the current status of the rope windpump technology in Nicaragua and to give recommendations for improvement and a possible transfer to other countries in Latin America. The findings of the evaluation will serve as input for the subsequent project phases.

In brief, the evaluation focuses on the following aspects:

- construction and design
- social acceptance and gender issues
- possible applications
- manufacturing methods
- production and installation
- maintenance and operation
- investments, recurrent costs and benefits
- performance and system efficiency

The project provided for a debriefing meeting with the Embassy to discuss the preliminary results and general progress. This meeting took place at the end of the evaluation mission on 22 April. During this meeting, the major findings of the mission team were discussed and were found sufficiently encouraging to continue the project.

4.2 Phase II: Dissemination of Results

The outcomes of the evaluation were presented during two workshops organised in Nicaragua, one for the national market and one for Central and South America. At the outset of the project, it was envisaged to start Phase II well after the expected completion of the evaluation. As Phase I started much later than planned, there was insufficient time to present the evaluation report in full during the workshops. Instead, a summary was prepared and used.

The first, national workshop was held on Friday 24 April. It had an informative and promotional character, as the rope windpump has already a record of more than five years in the country. The main objective was to draw the attention -once again- of many institutions involved in rural development to the possibilities of this pumping technology. This workshop was visited by almost a hundred people.

The international workshop held from Monday 27 till Wednesday 29 of April, brought together 12 people from 8 different countries in Latin America (outside Nicaragua). These people were carefully selected from among potential manufacturers and organisations active in rural development with a serious interest to start promoting and/or producing the rope windpump in their home countries. Their transfer to and stay in Managua was made possible thanks to funding by the Royal Embassy of the Netherlands under this project.

This workshop focused on discussing the possibilities for transfer to other countries, and viewing the potential fields of application outside Nicaragua. Also, it was used to pre-select the candidates with whom to start the first dissemination step scheduled as Phase III.

Summarising, the following objectives were pursued in this phase of the project:

- presentation of the rope windpump technology to an interested public
- discuss the possibilities and constraints for transfer of the technology to manufacturers in Latin America
- establish contacts with manufacturers or organisations interested to start production in their home country
- to select four candidate manufacturers to start transfer of the technology

4.3 Phase III: Transfer of Technology

At the outset of the project, CESADE knew about several manufacturers and organisations in Latin America that were interested in producing the rope windpump. It was therefore decided to benefit of the momentum and contacts created during the workshops and include a first dissemination step into the project. This element (Phase III) would cover the transfer of a demonstration rope windpump to four manufacturers Central and South America with a serious interest in producing, promoting and commercialising the rope windpump. In order to show their commitment, they would have to bear part of the total cost of the transfer. The transfers scheduled in this phase would include the following "package":

- drawings and manuals
 - transport of pre-manufactured components
 - production of several parts (tower and rotor) in the target country
-

- local assembly of one (1) rope windpump in the target country
- installation of this rope windpump
- training of local technicians on basic design, production, installation and maintenance

The transfers were executed jointly by CESADE (Mr. Enock Matute and Mr. Henk Holtslag) and AMEC (Mr. Luis Román), who supervised the production and installation of the demonstration rope windpump in the target countries. The first two transfers, which were realised in Peru and Bolivia, took place in September 1998. The third and fourth transfer to Guatemala and Cuba started in October, but were interrupted by the hurricane "Mitch". After discussing the situation with the Embassy, a prolongation of the project was granted and the transfer activities were resumed in February and March 1999.

Some parts of this windpump were pre-manufactured in Managua and shipped in order to save time. CESADE has followed this method previously with positive results and it was therefore also applied in this project. After this first experience with the rope windpump in his home country, the receiving manufacturer is expected to have sufficient knowledge to handle the equipment and demonstrate it to interested customers.

5. COLLABORATING PARTIES

The project is a joint effort of the Centro de Estudios y Acción para el Desarrollo (CESADE), Managua, and RED Renewable Energy Development vof from Eindhoven, The Netherlands. RED is the overall manager of the project.

In the execution of the project, experts from Latin America were involved whenever possible to improve the exchange of knowledge and experiences in the region, and to create opportunities for future co-operation.

The following people and organisations were involved in the project:

Team leader:

- Mr. Jan de Jongh, RED vof, Eindhoven, The Netherlands

General support team CESADE:

- Mrs. Melba Reyes Gómez, CESADE, Managua
- Mr. Enock Matute, CESADE, Managua
- Mr. Henk Holtslag CESADE, Managua
- Mrs. Ivania Pérez, Managua
- Mr. Fanor, Managua

Technical assistance and support:

- Mr. Luis Román, Taller AMEC, Managua
- Mr. Remi Rijs, RED, The Netherlands

Evaluation mission:

- Mr. Jan de Jongh, RED vof, Eindhoven, The Netherlands
- Dr. Simon Batchelor, Gamos Ltd, Reading, United Kingdom
- Mr. Mauricio Gnecco, FDTA, Villavicencio, Colombia

End-use survey:

- Dr. Antonio Belli, CICUTEC, Managua
- Mr. Mauricio Gnecco, FDTA, Villavicencio, Colombia

Measuring programme:

- Mr. Gustavo Jiménez Soto, ERA, Cartago, Costa Rica
- Mrs. Celina Vindell Cisne, Universidad Nacional de Ingeniería UNI, Managua
- Mrs. Indiana Inestroza López, Universidad Nacional de Ingeniería UNI, Managua
- Mr. Jan de Jongh, RED, The Netherlands
- Mr. Remi Rijs, RED, The Netherlands

PART B:
FINDINGS OF THE EVALUATION

1. WINDPUMPING FOR DEVELOPING COUNTRIES

Windpumps are mechanical windmills that are used to drive a pump for lifting water. They can supply water for a variety of users, work in remote areas to provide water for livestock and in villages for community water supply. Smaller windpumps are used for low-lift irrigation, drainage and salt production. Large windpumps can supply water for irrigation of cash crops.

The amounts of energy involved in water lifting are relatively small. For example, a volume of 10 m³ of water per day is sufficient for a village of 250 people (WHO norm of 40 l/day per capita). The nett energy needed to lift this amount of water from a depth of 35 m is not more than approx. 1 kWh (equivalent to an average nett power of only 40 W per day). Such amounts of energy can be supplied by a windpump with a rotor of 3 meter diameter, if the average wind speed is 3.5 m/s or higher. If the pumping depth (the "head") is larger, the volumes become smaller: to pump water from a deeper well costs more energy. (In windpumping terminology, one often uses the product of volume and head as a measure for the energy input; the unit is "m⁴" and 367 m⁴ is equivalent to 1 kWh [2]).

To give an indication of the impact windpumps may have for water supply in the rural areas, one may state that (simplifying matters somewhat) the 300 windpumps in Kenya deliver water for about 200,000 people in remote areas, thereby contributing to a better quality of life.

WINDPUMP MARKET SEGMENTS WORLDWIDE			
Application	Users	Countries	Comments
large cattle farms	wealthy farmers	worldwide	established markets for 1 st generation windpumps
irrigation	farmers, usually with a few hectare	worldwide	for high value crops; low cost and 2 nd generation windpumps best suited
agro-forestry / afforestation	innovators and wealthy farmers	Cape Verde, India	very small market at present; 2 nd generation and low-cost are best suited
low head	individuals; communities	Thailand, Vietnam, China	for salt pans, shrimp/fish raising; low-cost designs used, some attempts with 2 nd generation designs
homesteads and small farms	farmers and rural families	worldwide	often mixed domestic, livestock and irrigation; 1 st and 2 nd generation best suited
domestic water for community use	villages, small communities around missions, hospitals	worldwide	social/institutional implications, often external funding; 1 st and 2 nd generation best
nomadic livestock	nomadic people	Colombia, Kenya, Sahel	use for people and animals; environmental / social aspects are important; 1 st generation preferred
community agriculture	small groups in rural areas	Sahel	cultivation of crops for village use; 2 nd generation windpump suited

Table 1.1 Classification of market segments for windpumps with the corresponding user groups and applications (based on [3]). For the last column, see the explanation in section 1.3.

Windpumps can be an attractive solution with many potential applications. Table 1.1 shows the market segments identified in [3], with the corresponding applications and user categories. However, the introduction of windpumps in developing countries is not easy. Potential users are not often aware of the possible options for water pumping in their specific situation: they have a lack of information of the resources; they need information about technologies and need training on operation, maintenance and choosing the right option. An infrastructure for maintenance and assistance should be set up, and the whole implementation process should be monitored in order to learn and detect problems in an early stage. In general, the awareness of possible applications of

windpumps is low, not only among the potential users but also among the international donor and assistance organisations.

1.1 The Niche for Windpumps

Among the several options for water pumping in rural areas there is a niche for windpumping in the energy range of 20 m⁴ to 2,000 m⁴ as discussed in [4] (see Figure 1.1). The corresponding machine sizes roughly vary between 1 to 7.5-m rotor diameter.

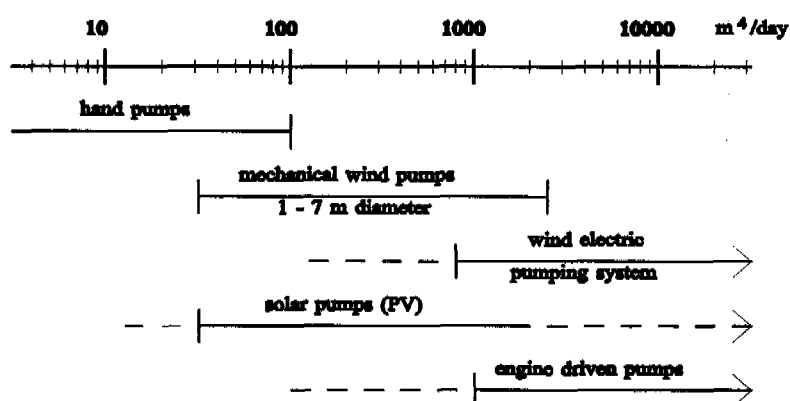


Figure 1.1 The niche for windpumping applications (from [4]). The unit m⁴/day is the product of the head in meter and the pumped amount of water in m³/day. This unit is proportional to the energy needed for pumping this amount of water per day (367 m⁴ is equivalent to 1 kWh).

It is seen that, at the low end of the scale, windpumps have to compete with the simpler handpump and solar pump; at the high end, mechanical windpumps become less attractive as the rotor diameter becomes too large.

1.2 Wind Pump Manufacturing

There are about 100 windpump manufacturers in the world. The longest established manufacturers are found in the "traditional" countries: the USA, Australia, South Africa, Spain and France. Here the technology became a very important asset, mainly for cattle watering and for the exploitation of large extensions of land during the second part of the 19th century and the first decades of this century. The windmills from those days are generally known as "first generation" wind pumps. Although their heyday is over and they have been replaced by electric pumps it is estimated that at present about one million of them are still in operation.

In developing countries the implementation of windpumping has been -and is- much more difficult. Manufacturing skills are different, as well as the conditions for operation and maintenance. And of course, the user usually has little or no money in his pocket. For these reasons, the "first generation" windpumps do not have a large market in developing countries.

In the beginning of the 1970s, a new kind of windpump was developed to address the specific conditions in developing countries: a "second generation" of windpumps was born. In many cases there was input from universities and research institutes in the industrial world, to assist in the

development of these windpumps. One of the challenges of the second generation windpump was to enable local production: a well-designed second generation windpump constructed in a developing country can be much cheaper than an imported first generation windpump.

Local manufacturers often develop a windpump on their own but their businesses are small and lack financial resources, technical and marketing skills. Often their windpumps are not suited for the market they try to serve, and the manufacturer is not aware of better models that may exist elsewhere. Most of them sell only a few dozens or less per year. The products need further development, which is mainly done by trial and error.

In some developing countries there exist cheap, artisanal windmills built from local materials. They generally have a short lifetime, are not very efficient, and the design is fully empirical. On the other hand, they are an element in the tradition of people and well adapted to the local geography, climate and culture.

In the beginning of this decade, the annual production of windpumps worldwide was estimated at between 5,000 and 8,000 units, of which about 20% took place in developing countries. The predominant type produced in the developing countries is the second-generation wind pump [3].

1.3 Characterisation of Windpump Types

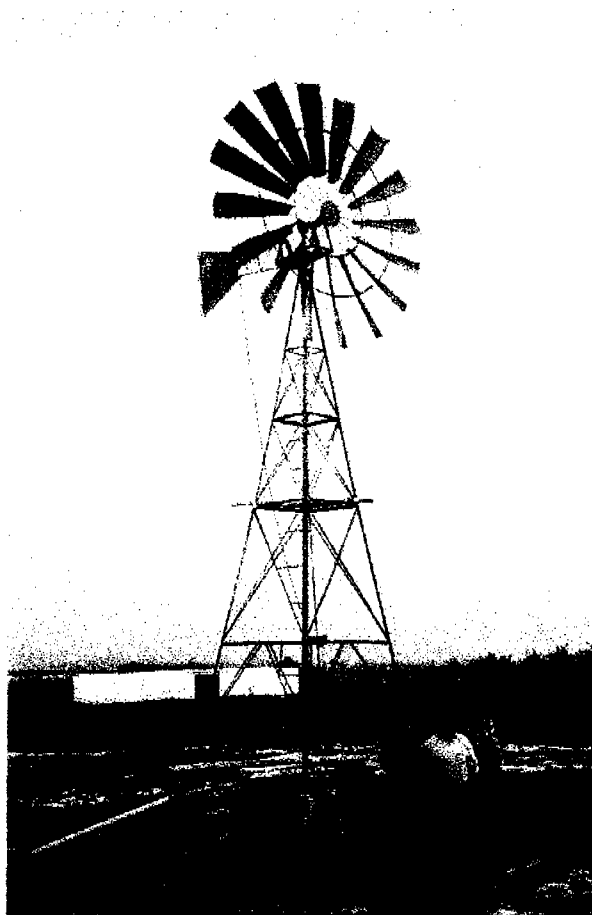
As seen in the previous section, the windpump family counts three different types of windpumps:

- first generation windpump (also called "American" type windmill)
- second generation windpump
- artisanal windpump

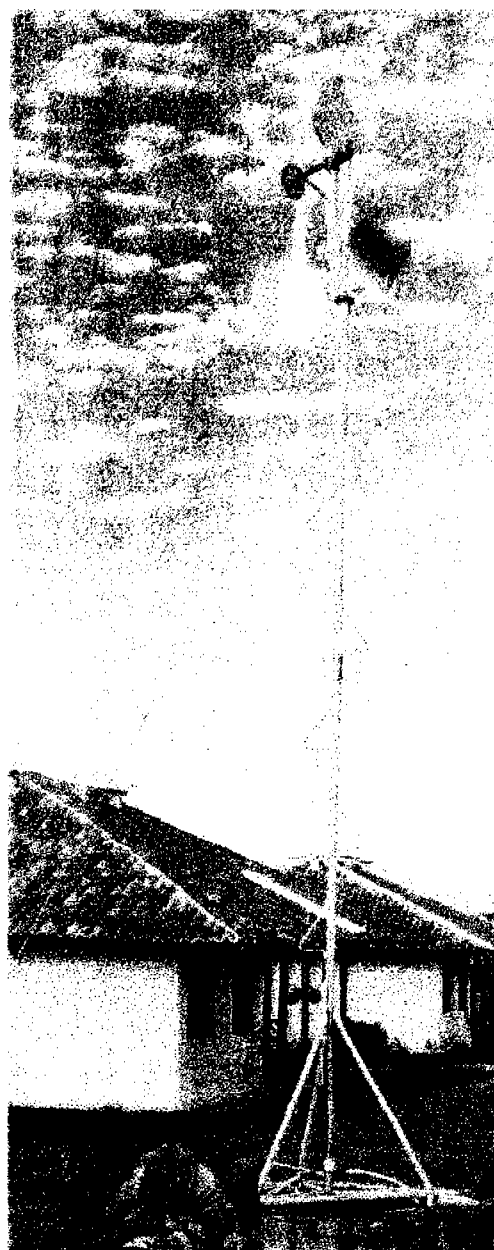
The characteristics of each of these windpump types and the differences between them, are summarised in :

Type	Characteristics	Strong points	Weak points	Cost
American windmill	multi-bladed slow running back-gearred	long life highly reliable little maintenance	high weight complicated installation	high
second generation	less rotor blades fast running no gearbox	"easy" production light-weight cost-effective	technology not always proven	moderate
artisanal	simple design local, cheap materials	local production high user involvement low initial costs	short life-time much maintenance high unit water cost	investment: low maintenance: high

Table 1.2 Characteristics of the three classes of windpumps: the "American" windmill, the second-generation windpump and the artisanal windpump type.



Above: Example of a second generation wind pump in Peru manufactured by Zimic



Right: Example of a second generation wind pump from Colombia, type Gaviotas

1.4 A Review of Artisanal Windpumps

In this section the most important artisanal windpumps are described, to set the context for the Nicaraguan rope windpump. In fact, the latter is a second-generation windpump but its production, operation and maintenance concept make it more comparable to the artisanal windpumps.

ARTISANAL WINDPUMPS WORLDWIDE					
Country	Type	Characteristics	History	Applications	Numbers
"traditional"					
Greece, Crete	sail-wing	multi-bladed slow running back-gearred	centuries	irrigation	1000 (?)
China	FC-7.5; FCG-7; FCG-8; FD-2.6/WJF; XFT-6/WJF	sail cloth rotor (bamboo reinforced)	1965 and later	unknown	unknown
Thailand	Dragon bone	wood	centuries	low-head pumping	> 1,000
Cape Verde	artisanal	scrap material		salt production	100
Peru	Miramar	wood and scrap	1920's	low-head irrigation	1,000
Philippines	bamboo	bamboo, steel	unknown	low-head pumping	
"improved designs"					
Thailand	Vita-V-8B	USA-Vita design, for Lumpun, Phattalung	1980	irrigation	10
Mali, Niger	Sahores	IT Dello (France) design, wood, steel blades	1980's	irrigation	10
India	12-PU-500	WOT (Netherlands) design (large but failed project)	1970's	irrigation	2,000
Kenya	HEWA	S. Batchelor (UK) design	1980	irrigation	> 100
Niger, India	Crete type	WOT (Netherlands) improved design			2 (Niger) 2 (India)
	Alborado	steel	1990	low-head irrigation	10
Peru	Miramar II	GTZ (Germany) improved design	1983	low-head irrigation	unknown

Table 1.3 Locally developed artisanal windpumps and machines improved with external inputs (source: internal documentation RED).

Artisanal windpumps mostly have a simple design and are made by local craftsmen using materials such as wood, sail or steel. Wooden bearings are mainly used instead of an industrial roller or bush bearing. For the production, only simple equipment is required.

The initial investment is low, sometimes 4 to 5 times less than the price of a comparable first or second-generation windpump. The low price is due to the simplicity of the design, required manufacturing skills and the use of cheap local materials. A lot of maintenance is needed to keep

these windpumps running, and the recurrent costs are for the most part higher than for a second-generation windpump. The lifetime is relatively short.

Artisanal wind pumps are mostly used for irrigation or salt production. Their market consists of farmers with little money whose labour costs are low. Artisanal windpumps with a long tradition can be quite effective. Examples are the Dragon Bone or "bamboo-mat" windpump in Thailand; the "Miramar" low-head irrigation pump in the North of Peru; and a number of local designs in China. A typical characteristic of the artisanal windpumps is that they are developed with little or no exchange of information: they are found scattered all over the world and linked to the region or village where they are used. In general, scientists and organisations funding rural development have ignored them. In recent years however, there have been several attempts by foreign aid organisations to improve local windpumps. Table 1.3 gives an overview of applications worldwide.

1.5 Windpumping in Nicaragua

In the beginning of the century many first generation windpumps were imported in Nicaragua. The most common types are the Chicago Aermotor and Dempster imported from the USA, and the Australian Southern Cross. The market for these expensive machines mainly consisted of the relatively rich cattle farmers and their total number reached up to about 1,000 units. It is estimated that at present several hundreds of these machines are still in use in the country. Since there are no dealers in the country, maintenance is done by local workshops in Managua.

Around 1980, there have been several attempts to produce windpumps in Nicaragua, such as the CITA-INRA (Centro de Investigaciones en Tecnología Apropiada - Instituto Nicaragüense de Reforma Agraria) project and the development of the "Danto" windpump by a German project. None of them has been successful. Between 1986 and 1990, the Dutch government supported a project executed by SNV to encourage the use of wind energy for irrigation purposes. Within this project, technical and financial assistance was given to the state-owned company Industrias Metalúrgicas del Pueblo (IMEP).

IMEP produced a copy of a "first-generation" windpump between 1985 and 1990, which is known as the IMEP3000. Of this model, about 70 units have been produced and installed. The price was about US\$ 2,200,- (price level 1990). In 1990 the production was suspended by the factory, and it is estimated that about half of these windpumps are still in use.

IMEP also produced a "second generation" windpump known as the IMEP5000. This machine was based on the Dutch CWD5000 windpump and introduced within the framework of the IMEP project. This machine costing about US\$ 4,000,- (1990) turned out to be too complex and expensive for Nicaraguan conditions and only 3 units remain in service of the 10 units produced altogether.

Although the introduction of the IMEP5000 was not a success, it provided useful lessons for the future development of the rope windpump and actually stimulated its development.

Artisanal windpumps have never been built or used in Nicaragua as far as known. Low-cost models such as the Gaviotas (Colombia) and Miramar (Peru) have never been copied or imported to Nicaragua.

With the development of the rope windpump, a new chapter has been added to the history of windpumping in the country. It will be described more in detail in section 4.

1.6 Windpumping in the Target Countries (Peru, Bolivia, Guatemala and Cuba)

1.6.1 Peru

Windpumping has a considerable history in Peru, mainly in the long, deserts coastal area between the Pacific Ocean and the Andes. Wind resources are quite good in Peru, especially in some parts of the coast (Piura, Trujillo, Paracas) and many of the valleys near the coast and in the Andes. In the rainforest (the "Selva" region) wind speeds are very low.

In the lower parts of the valleys and along the coast line, water can be pumped from the underground, which shows abundant in aquifers on a depth between 10 and 40 m. In the North of Peru, the narrow coastal desert broadens to the wide and flat desert of Lambayeque and Piura. Here along the rivers Chira and Piura, since the beginning of this century local farmers apply selfmade, artisan windpumps to lift water from the river for irrigation. It is estimated that more than 1,000 of these windpumps –the Miramar- have been in use, until most of them became destroyed due to the floods and storms caused by "El Niño".

In the South of Peru, in Arequipa, windpumping has become popular thanks to the existence of a local manufacturer, Segovia. Here the windpumps are mainly used for the household and watering of the parcel ("la chacra").

In the mayor cities of the country (Lima, Trujillo, Chiclayo, Arequipa) exists a number of windpump manufacturers that still produce windpumps. In general, the experiences in the country are not very positive due to insufficient maintenance, design problems and the unsuccessful introduction of foreign machines. During the eighties, the state intitute ITINTEC was involved in the design and construction of windpumps and is still renowned for its work. Later, the 12PU500 windpump designed by the WOT (Twente University in the Netherlands) was transferred to Peru and copied and produced by Workshop Ricardo Zimic and by Grupo (Universidad Católica). After "El Niño" in 1983, the German GTZ started a project to upgrade the traditional Miramar design. However, the machine that resulted was not only more resistant but also more costly and could not prevent many farmers from leaving the region and migrate to Chiclayo.

1.6.2 Bolivia

Bolivia is a country with an important demand for small-scale water supply. Due to the varied and complex geography, local conditions vary from place to place, with the Indian population living on the Altiplano and the mountain valleys, agriculture in the Yungas and a waste area in the lower oriental part of the country with, for instance, cattle farming. In this region, around Santa Cruz, windpumping has a considerable history. In the other parts of the countries, especially the mountains, the infrastructure for water, transport and electricity is generally poorly developed. In many parts of the country however, there are sufficient wind and water resources available to make windpumping a possible option.

Besides the Fiasa windpump imported from Argentina, there have been several intents in the past to set up a local production. The SEMTA factory for example produces a windpump based on the Dutch 12PU500, but has not been very successful. Also the University of Bolivia has developed and produced a windpump for some time. In general, one has underestimated the technical complexity of a windpump and once they suffered problems in the field, the suppliers did not have the capacity to address them. Apparently, windpumping would require a better co-ordination and knowledge infrastructure in order to become a reliable pumping option for all market sectors. There are a number of organisations active in the country that are working on sanitation and water supply; they might consider windpumping in the future as a useful technology.

1.6.3 Guatemala

Guatemala is a trade wind country the same as Nicaragua. The geography of the country varies, from the mountainous highlands in the Western part to the tropical lowland in the East. There are several hundreds of windpumps in the country but many have fallen in disuse on places that now have access to electricity. There is no local production of windpumps, but several companies (Topke, Agritop) who sell the classical "American" windpump model, imported from Mexico and Brazil. The current annual sales are calculated at not more than several tens of windpumps.

In the country there is an important need for small-scale water supply, probably comparable to Nicaragua. Since the social, economic and cultural context is more comparable to Nicaragua than in one of the other target countries, one may expect interesting opportunities for the rope windpump technology in Guatemala.

1.6.4 Cuba

Windmills for water pumping are quite common in Cuba and are mainly used for cattle watering and household use. Currently their number is estimated at between 7,000 and 8,000 units.

The windpumps are produced by several local industries such as Taino, Acinox and others. They are of the "American" multiblade type with 12 to 18 blades and equipped with a piston pump. The sales price to farmers is subsidized but is still between US\$ 800,- and US\$ 1,200,- for a size comparable to that of the rope windpump.

Since rural electricity by now has covered about 90% of the country, but also because of the high cost and investment, the use of windpumps has declined during the last decade. However, there is still a demand for new windpumps in areas with no electricity supply and regions where cattle breeding is expanding.

The wind potential in Cuba is considered fairly good, and there have been some studies by the Spanish wind turbine manufacturer Ecotecnia for a wind farm in the eastern part of the country.

2. WIND RESOURCES IN NICARAGUA

The global wind regime in Nicaragua is determined by trade winds coming from the Caribbean in the Northeast. The winds pass the rainforests in the eastern part of the country to slow down over the central mountains to reach the plains and lakes near the Pacific Coast. This is the part where most of the population is concentrated (see Figure 2.1).

In flat terrain, the wind direction is quite constant during a large part of the year and dictated by the trade winds. This is the case in the western part of the country and east of Lake Managua and Lake Nicaragua. In the valleys and mountains, the wind direction can deviate from this general pattern due to the local topography and will be much more variable.

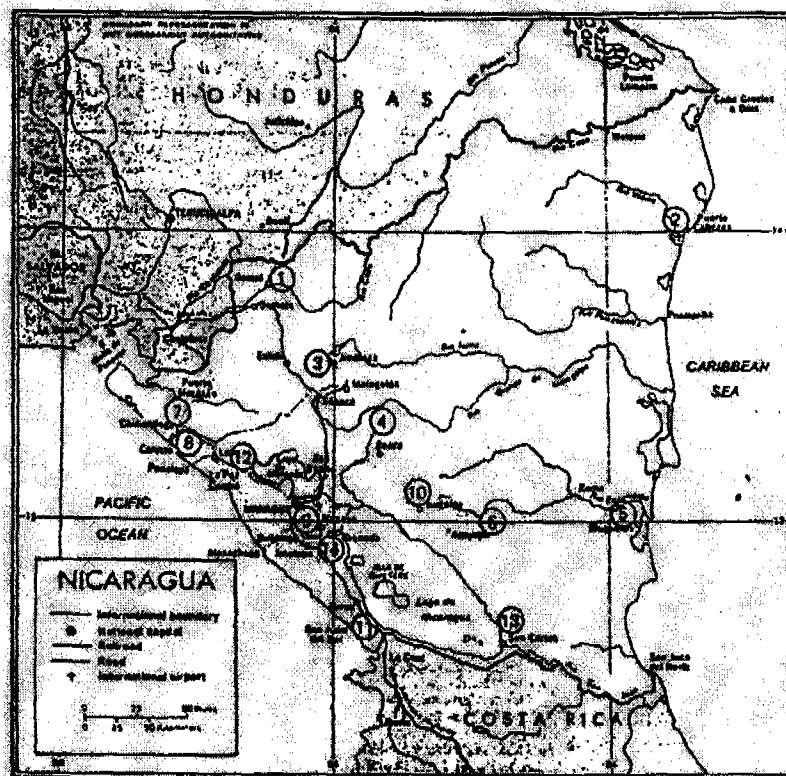


Figure 2.1 Map of the territory of Nicaragua based on Alberts and Mueller [5]. Indicated are the meteorological stations that provided the wind data analysed by these authors. The data from the most reliable stations are used in this report to estimate the wind potential for windpumping.

2.1 Existing wind data

In literature [5], [6], [7], wind data are given from meteo stations to give an indication of the wind potential in the country. The reliability of some of the stations and the performed recordings is

questionable, as analysed by Mueller and Alberts [5]. In Table 2.1, the data from the most reliable stations are shown.

Meteo stations in general do not provide useful information for wind energy purposes (see for a discussion on this matter, for example [8]). Among a number of reasons, they are usually situated on sites not suitable for evaluating the wind potential and often surrounded by buildings or trees. As a general rule, they under-predict the wind potential in a country. It is reported that new wind measurements are being taken for large-scale, commercial wind energy projects for electricity generation; however, the mission did not have access to them.

AVERAGE WIND SPEED IN NICARAGUA														
Station	Monthly Average Wind Speed [m/s]												Average	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Dec-Apr
Ocotal	3.1	3.3	3.6	3.3	2.5	2.5	3.1	2.5	1.9	1.9	2.2	2.8	2.7	3.2
Puerto Cabezas	6.1	5.5	6.1	5.8	5.5	5.5	6.1	5.5	5.0	4.7	5.5	5.8	5.6	5.9
Muy Muy	2.5	2.8	3.1	3.1	2.2	1.9	2.2	1.7	1.7	1.7	1.9	2.2	2.3	2.7
Villa Sandino	4.7	4.4	4.4	5.0	3.9	3.3	3.1	2.5	2.5	2.5	3.3	4.2	3.7	4.5
Chinandega	2.5	2.8	2.5	2.5	2.2	1.7	1.9	1.9	1.9	1.7	1.7	1.9	2.1	2.4
Managua Sandino	3.6	3.9	4.2	3.9	3.3	2.5	2.8	2.8	2.2	1.9	2.2	2.8	3.0	3.7
Juigalpa	4.4	4.4	4.2	4.2	3.1	2.8	3.6	3.1	2.5	2.5	3.3	4.2	3.5	4.3
Nagarote	4.7	4.7	5.0	4.7	2.8	2.8	3.3	3.1	2.2	1.7	2.2	3.3	3.4	4.5
San Carlos	1.9	2.2	2.5	2.2	1.7	1.7	1.7	1.4	1.4	1.4	1.4	1.7	1.8	2.1
Granada	4.2	4.7	4.7	4.4	3.3	2.8	3.3	2.8	1.9	1.7	2.8	3.6	3.4	4.3

Table 2.1 Average wind speeds for a number of meteo stations in Nicaragua, adopted from [5]. Note the increase in wind speed during the dry season (December - April), compared to the yearly average wind speed (last two columns).

Figure 2.2 shows the monthly wind pattern as calculated from the data in Table 2.1 by weighing all stations equally. The figure may give an impression of the variations in wind speed as occur during the year. One can clearly recognise that wind speeds are significantly higher in the period from November till May, which coincides with the dry season. Also indicated in the figure is the annual average wind speed as calculated by averaging the mean values for all stations. This average annual wind speed is found to be equal to 3.1 m/s but should be considered as a reference value only. Obviously, a more sophisticated manner of attributing the weight factor to the stations is needed to obtain a realistic estimate of the average wind speed in Nicaragua.

The recorded values at the stations are rather modest for a country where most people confirm that there is plenty of wind. The flagging trees that can be observed in some areas (e.g. on the Cruceros near Managua) are another indicator for good wind potential.

It is likely that new data -once they are published- will indicate substantially higher values during a large part of the year. In a number of neighbouring countries, first of all Costa Rica, wind turbine plants (wind farms) are under development. These are only economically viable if the average wind speeds are high. Probably the presented data underestimate the wind potential in the region considerably.

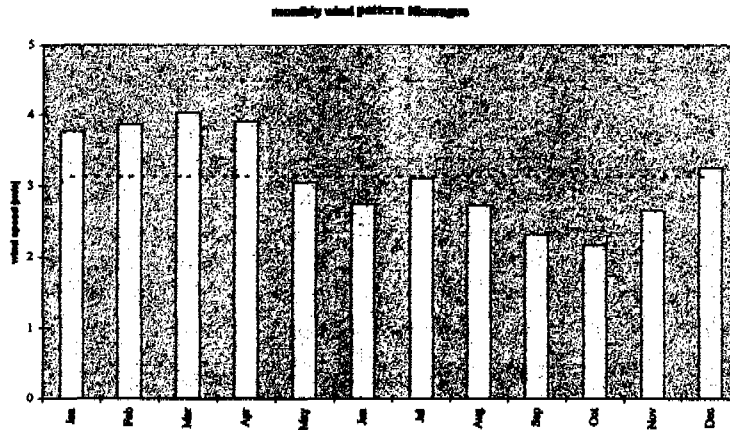


Figure 2.2 Average monthly wind speed distribution in Nicaragua as obtained from the information from the meteo stations in Table 2.1 [5]. The dashed line indicates the annual average wind speed (about 3.2 m/s) in the country obtained by averaging over all stations.

Trade wind areas such as the Nicaraguan territory generally show a diurnal variation in wind speed as well. This behaviour was confirmed during the mission and the "technical" measurement programme. Data obtained during two weeks of measurements along the Carretera Vieja a Leon, show that the average wind speed measured between 12:00 pm and 5:00 pm during the afternoon is generally significantly higher than the average wind speed measured over 24 hours (Figure 2.3). This indicates a diurnal pattern with peak wind speeds in the afternoon hours.

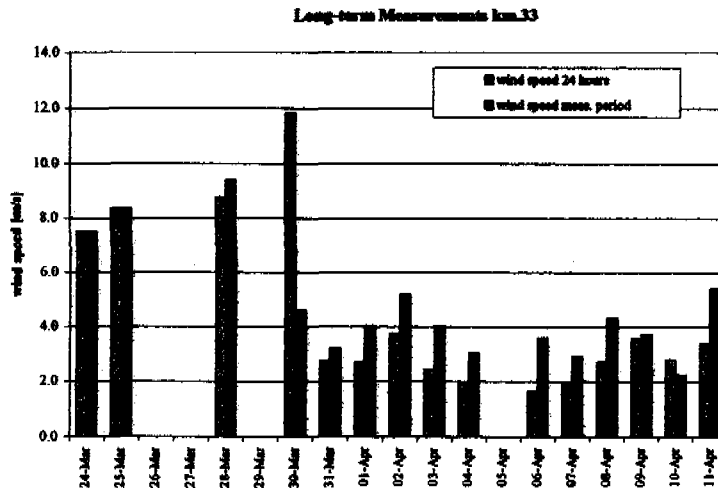


Figure 2.3 Difference in average wind speed during the measuring period in the afternoon (12:00 pm - 5:00 pm) and last 24 hours. The afternoon values are systematically above the daily average, which is an indication of a diurnal pattern with the higher wind speeds in the afternoon hours. Measurements carried out by manual wind run recordings during two weeks at Carretera Vieja a Leon, km. 33. Such a diurnal wind pattern is typical for a trade wind area.

Two sites with a same average wind speed but a different diurnal pattern may have a very different wind potential. A site with a strong diurnal pattern, i.e. some hours of wind speeds above the average value and some hours of wind speed below the average, has a higher wind potential than a site with a constant wind speed during the whole day.¹

In case of the Nicaraguan rope windpump, the designers have adapted the system to the presence of strong winds in the afternoon during the dry period. The major part of the wind energy flux is captured during the afternoon and is used to drive a large pump that lifts a large amount of water during a few hours. The lower wind speeds during the rest of the day are too weak to operate the windmill, and no water is pumped at all. This implies that the windmill is turning only a limited number of hours per day (compared to a system equipped with a smaller pump). This reduces the *availability* of water to the farmer. In general, a low availability is considered a drawback as a farmer cannot be confident to have water available at all times. However, because of the specific wind conditions and use of the rope windpump with a storage tank, the lower availability per hour is not much of a problem, since the availability over a day is not affected.

2.2 Wind Potential for Windpumping

Windpumping is often a least-cost option if the average wind speeds are above 3.5 m/s. The data indicated in Table 2.1 show an average wind speed of 3.1 m/s over a year and of 3.8 m/s in the dry period (from December to April). This indicates sufficient potential, at least during part of the year. In particular areas (Granada, Juigalpa, Puerto Cabezas), the available wind potential is considerably higher. The fact that the higher wind speeds coincide with the dry period is favourable for the application of windpumps. During this part of the year, the wind direction is mainly northeast.

High wind speeds (or gusts) are very rare in the country: the maximum wind speed reported by the AMEC workshop in Managua has been of 33 m/s (since 1990). No information on the maximum wind speed was found from other sources.

Another strong argument to support that windpumping is feasible in Nicaragua, are the hundreds of traditional windpumps that have been in use for decades throughout the western part of the country for cattle watering.

¹ This is explained by the fact that the energy in the wind is proportional to the cube of the wind speed. (Example: site A with a wind speed of 4 m/s during 24 hours has a wind potential proportional to $0.5 \cdot \rho_{air} \cdot 24 \cdot 4^3 = 922 \text{ Wh/m}^2$, in which ρ_{air} is the density of air (1.2 kg/m^3); site B having 6 m/s during 12 hours and 2 m/s during the other 12 hours, has a potential proportional to $0.5 \cdot \rho_{air} \cdot (12 \cdot 6^3 + 12 \cdot 2^3) = 1,612 \text{ Wh/m}^2$. Both sites have the same average wind speed over 24 hours, i.e. 4 m/s.)

3. THE ROPE HANDPUMP IN NICARAGUA

3.1 Introduction

The principle of the rope and washer pump dates from centuries ago and has been described for example in [9]. According [10], the rope pump was introduced to Nicaragua several decades ago, but the first designs were reported to be rather inefficient because of the inappropriate use of local materials and insufficient understanding of its principles.

A rope pump consists of four main components: a riser tube through which water is lifted to the surface; an "endless" rope with washers at regular distances; a top pulley with a handle to operate the pump; and a ceramic bottom end to guide the rope. The working principle of the rope pump is straightforward and can be derived from Figure 3.1

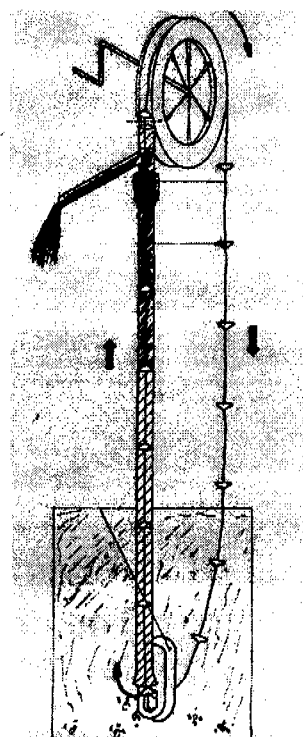


Figure 3.1 Main components and working principle of a rope pump.
Figure derived from [14].

In 1983, the rope pump concept was picked up again by the Centro de Investigaciones en Tecnología Apropiada - Instituto Nicaragüense de Reforma Agraria (CITA - INRA) in Managua. The first goal was not to develop the technology, but to demonstrate the potential of the rope pump as a means to provide water to rural communities by making use of their own capacities. The transfer of the technology within the immediate environment of CITA - INRA in Estelí, was achieved through "action-oriented" workshops with the residents of the Santa Cruz community. As a result, the people started to make their own pumps, using PVC pipes and pistons supplied by CITA - INRA. The farmers were also informed on "theoretical aspects" of the pumps. By the end of 1984, rope pumps were also produced and installed in San Nicolás and El Sauce and in municipalities north of Chinandega.

In 1984, the National Water Supply Institute INAA concluded that the rope pump was an interesting technology, but that it did not adequately meet their technical requirements. In 1985, the Ministry of Agriculture MIDINRA adopted a policy for more mechanisation and the introduction of a more large-scale economy in the agricultural sector. It was decided to close down CITA-INRA.

Several initiatives led to the start-up of an industrial production of the rope pump. In the mid-eighties, the factory HULETECNIC developed a prototype of a hand rope pump, using soft "rubber-alike" PVC pistons. HULETECNIC also produced different sizes of pistons cut from of rubber discs, using car tyres as a prime material, to meet the demand of an SNV/INAA project [27]. In 1987, the Universidad Nacional de Ingeniería and the Cooperativa San José started the development of an improved version of the rope pump. The industrial production, commercialisation and selling of the rope windpump effectively took off after the hurricane Juana in 1988, when international aid organisations requested 200 rope pumps for emergency water supply. Under guidance of the rope pump factory Bombas de Mecate S.A. de C.V. at Los Cedros, HULETECNIC started producing polyethylene pistons using the technology of injecting thermo-moulding plastics since 1990.

In 1990 the co-operation between the Cooperativa and the Universidad came to an end because of conflicting development philosophies [11]. Meanwhile, three institutions, the INAA, the Directorate for Rural Water Supply DAR, and the Dutch organisation SNV had begun introducing rope pumps in several parts of the country. (The latter organisation within the framework of the PASOC programme for water, sanitation and community organisation.)

In 1990, two rope pump promoters with experience in water supply projects in Nicaragua set up the commercial company Bombas de Mecate SA. They further improved the rope pump and started extensive promotion campaigns. The company has been very successful and in the course of 1990 already about 80 rope pumps were sold. At present (1998) about half of all the rope pumps in Nicaragua (6,000 out of a total of 13,000) have been produced by Bombas de Mecate [12].

Presently some seven workshops are producing the rope pump in Nicaragua for a price that ranges between US\$ 49,- and US\$ 90,-. The rope pump has been transferred to El Salvador and even to Colombia [13]. The existing products are still being further developed, particularly in relation to the capacities and purchase power of the different user groups.

Besides being a technically very sound concept, the most appealing characteristic of the rope handpump is that operation, maintenance and repair are done at family level. Rather than a village-level operation and maintenance ("VLOM") device, it is primarily a family-level operation and maintenance ("FLOM") device, which brings along a number of advantages.

At present, the rope pump supplies more than 11% of the Nicaraguan rural population with water. Family wells equipped with a rope pump serve about 6% of them, while donor financed village-level projects reach about 5% [27].

3.2 The Concept of the Rope Handpump

The rope handpump can be classified as a positive displacement pump, in which water is lifted by a chain of washers. The rope pump produces a constant output, unlike the pulsating flow of a conventional piston pump. It has a good efficiency and the design is not critical. If modern plastics are used, resistant against wear, it has proven highly reliable and is easily maintained and repaired by people in the rural areas.

As the weight of the water column is more or less equally carried by all washers in the up-going tube, the pressure built up in the rising main is only the height of the water column between two washers (mostly 1 m); in a piston pump (with a foot valve) this would be the height of the entire water column. As a result, the forces on the washers and the radial pressure on the rising main are very small, so that light, thin PVC pipes can be used. The continuous output flow not only reduces peak forces on the rope (which carries not more than the water column), but also maximises the effective

flow of water through a given tube diameter. Therefore, smaller rising main diameters can be used compared to a piston pump, and yet the outputs remain high. Finally, the absence of peak forces in the rope and the gradual filling of the rising main, contribute to a better adaptation to human ergonomics. All conceptual advantages allow a lightweight construction made from cheap materials, such as rubber and PVC.

In summary, the rope pump has the following strong points:

- As a "FLOM" pump, management problems are considerably reduced compared to "VLOM" pumps.
- It is ergonomically attractive, because the user experiences a smooth load and carries out a cyclic movement.
- Maintenance and repair is relatively simple, does not involve complex or expensive tools and can be done by the user.
- The diameter required for the riser pipe can be kept small, thanks to the non-pulsating flow.
- The pipe walls can be thin because the loads on the riser pipe are low both in axial and radial directions.
- The resulting total weight of about 10 kg is very low, compared to the weight of a classical piston pump (50 to more than 100 kg); this makes installation and lifting for maintenance and repair much more easy.
- It has a minimum of moving parts, which are not very critical: no valves, valve seatings, nor complex bearings are used.
- The volumetric efficiency of the rope handpump is reported to be 70 % [1] and about 85% for larger rope pumps [24].
- The use of plastic parts, concrete and ceramics makes the pump highly insensitive to corrosion.
- The pump can be installed on a narrow tube well, just like a piston pump; the 1/2" rope pump can be installed on a 2" tube well.
- It is cheap: US\$ 49,- to \$ 90,-, depending on the specific pump type and pumping depth.

Since the appearance of the IRC evaluation of the rope pump [1], it has increasingly been supported in Central America. Especially its low cost, easy repair and acceptance have shown to be strong assets in practice. The national institution INAA has chosen the rope pump as a national standard, while the "traditional" handpumps such as the Dempster, Afridev and Mark II/III are no longer applied. The market for the rope pump is both drinking water supply and sanitation as well as rural development applications (cattle watering, small scale irrigation, etc) [27].

A lot of work has been done already with respect to the international transfer of the rope handpump. This varies from network building (participation of the IRC and the Handpump Technology Network HTN, Unicef, the Worldbank and others); generating information and documentation packages (a photographic production manual in three languages, technical drawings, policy indications, etc.); and production of the rope handpump in various countries, apart from a continuous flow of information, correspondence and articles all over the world.

4. THE ROPE WIND PUMP

The rope windpump in Nicaragua is produced and sold by the workshop Aerobombas de Mecate (AMEC) in Managua, which has started production in the beginning of the nineties and until now, delivered and installed about 100 systems. Some 50% are in use for livestock watering, sometimes combined with irrigation, the others for small-scale irrigation together with domestic water supply. The position of the manufacturer and the end-users will be explained further on; in this section, a brief introduction is given to the concept and technology of the rope windpump.

The Nicaraguan rope and washer windpump or "Aerobomba de Mecate" can be classified as a second-generation, low-cost wind pump. The existing models in Nicaragua indeed are rather "simple" structures compared to conventional wind pump designs. They have a steel rotor and tower and operate a rope pump comparable to the rope handpump described in the previous section (see Figure 3.1). The transmission between the rotor shaft and the rope pump consists of two pulleys and a rope. If there is no wind, the pump can be operated by hand.

Locally available, standard materials are used for the construction; assembly can be done by a workshop without the need for sophisticated tools. The design philosophy builds forth on the rope handpump technology and relies on maintenance and repair actions by the user.

In general, the following criteria were applied for the design of the Nicaraguan rope windpump:

- low investment cost
- easy maintenance, which is done by the user
- application of a simple but proven pump type
- the use of basic tools and materials available on the local market

The resulting Nicaraguan rope windpump is quite a unique concept. It exhibits a number of design features from foreign windpump models. Most pronounced is the influence from CWD from the Netherlands (which was involved in the IMEP project in the eighties), mainly through the activities of Mr. Henk Holtslag in Nicaragua. Typical design details inherited from CWD are the rotor and the "hinged main vane" safety system [15].

Emphasis was put on the applied pump, as this had been one of the major technical problems encountered during the IMEP project. The use of a rope pump in combination with a wind rotor avoids many of the problems suffered by windpumps equipped with a piston pump. In the rope windpump, the load on the rotor and the pump is continuous, which reduces forces on the pump and windmill structure; this makes a lighter and more reliable structure possible. The characteristics of the rope pump also suggest an improved starting behaviour compared to a conventional windpump, which means a higher yield at low wind speeds.

4.1 The AMEC Rope Windpump

The rope windpump can be conceived as an extension of the rope handpump. It is not the only pumping system produced by AMEC that is based on the rope pump. Other systems are the bicycle pump (making use of human power), the animal traction pump (driven by an ox or a horse), and the motor pump (driven by an electric motor). All devices are designed to pump larger amounts of water than the rope handpump, which require a higher input power than can be provided by human (arm) force.

The mechanics of the rope windpump is easy to understand. A rope pump, similar to a rope handpump but somewhat larger and sturdier, is connected to a wind rotor on top of a tower. The transmission consists of a large rope that turns in a loop over a top (rotor) pulley and a bottom pulley on the pump shaft. If the wind is blowing strong enough, the rotor starts turning and operates the pump (see Figure 4.1).

The rotor head carries the rotor and a tail arm with a vane. The head assembly can turn freely around a vertical (or "yawing") axis. At low wind speeds, the tail vane directs itself parallel to the wind, turning the rotor automatically into the wind to make optimum use of the available energy in the wind. At higher wind speeds, the tail vane acts as a safety system to turn the rotor out of the wind. In this situation, the tail vane is lifted towards a horizontal position by the wind, which allows the eccentrically placed rotor to turn the head out of the wind. This limits the speed of the rotor to a safe value, even in very high wind speeds.

At this moment there is one limitation in the concept of the AMEC/CESADE rope windpump. The transmission rope limits the rotor head in its movements to turn itself into the wind, since it does not pass through the centre line (the yawing axis) of the tower but outside of it. To avoid the rope getting entangled with the tower if the rotor yaws too far from the "neutral" position (the right side in Figure 4.1) by a strong change in wind direction, the design is such that the rope runs of the top pulley. This behaviour is safe, but requires someone to readjust the rope. The rope windpump design is therefore more appropriate as the wind direction is more stable. This is not always the case.

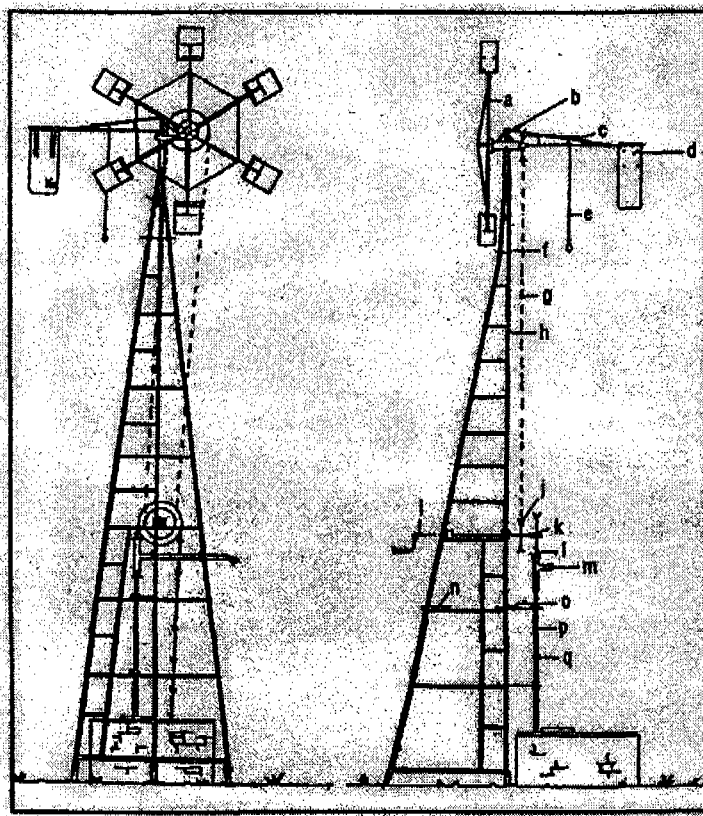


Figure 4.1 Layout of the AMEC H-270 rope windpump, based on [16]. Indicated are the following components: the rotor (a); the head assembly and yaw bearing (b); the top pulley (c); the tail vane (d); the control rope (e); the tower (f); the transmission rope (g); the tower (h); the handle for manual pumping (i); the pump shaft transmission pulley (j); the main shaft (k); the pump pulley (l); the pump discharge tube (m).

The standard type rope windpump produced by AMEC is officially known as the H-270 and is the model shown in the figure. The number "270" refers to the maximum freedom of the rotor head to orientate itself into the wind (which is 135° to both directions). If the wind comes from the back, the rope is pushed against the tower and runs off the pulley as described before. This makes the type more appropriate for regions with "unidirectional" winds (coming mainly from one direction). In many regions in Nicaragua, the wind direction is predominantly northeast during most of the year.

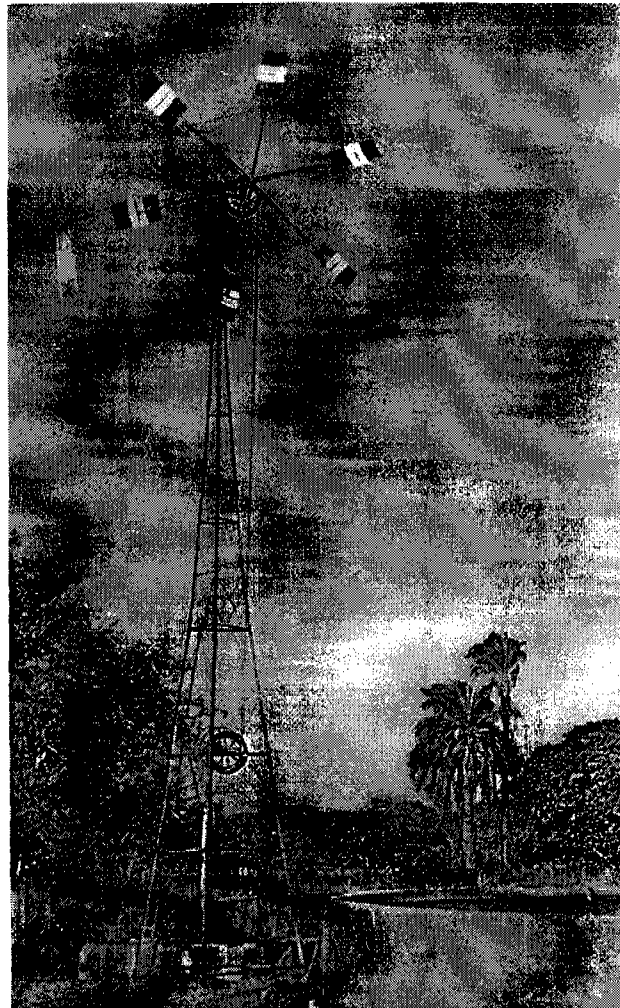
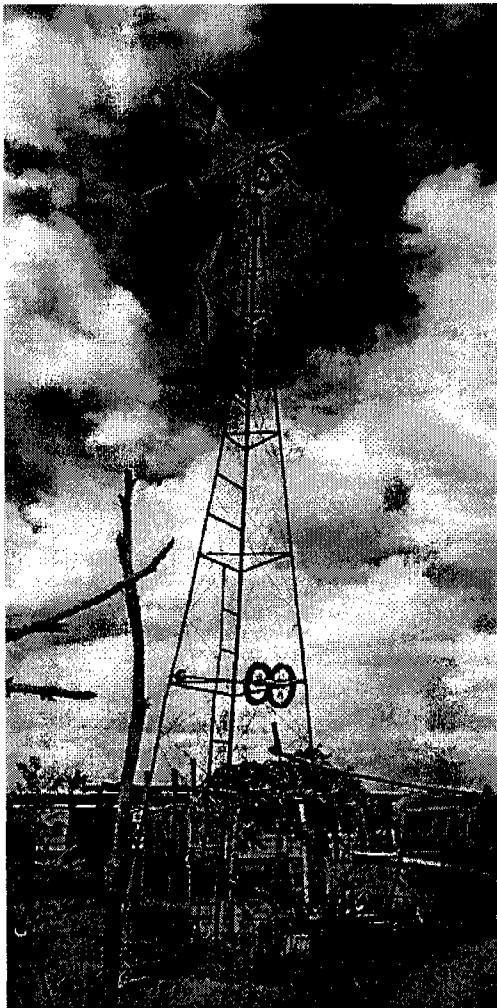
The H-270 exists in three different models with a rotor diameter of 8, 10 and 12 feet. Towers are offered with a height of 8, 10 or 13 m. The nomenclature used is for example H-270-8-10 (or briefly H-8-10) to indicate a windpump with an 8' rotor on top of a 10-meter tower.

AMEC's second windpump type has a head that can rotate over a full circle (360°) and has been developed for application in more variable wind regimes. This model, the H-360, is known as the *multigiratorio*, (literally "one that can make several turns"). The name is somewhat elusive however. At a half turn of the rotor (180° out of the "neutral" position), the upward moving transmission rope touches the downward going one. As this contact causes rapid wear, the rotor head must be brought back into its original position by hand. This means that also the *multigiratorio* cannot be left unattended for a long time, although it often returns into the original position by the wind itself.

Table 4.1 gives an overview of the different windpump models that are currently produced by AMEC.

DIFFERENT ROPE WINDPUMP MODEL PRODUCED BY AMEC					
	Model				
	H-8 (270)	H-8 (360)	H-10 (270)	H-10 (360)	H-12 (270)
rotor diameter	2.4 m	2.4 m	3 m	3 m	3.6 m
tower height	7 m	7 m	7 - 10 m	7 - 10 m	10 - 13 m
maximum lifting height above ground level	2 m	2 m	3.7 m	3.7 m	3.7 m
maximum pumping depth	20 m	20 m	35 m	35 m	45 m
Output at 10 m head	25 l/min	25 l/min	40 l/min	40 l/min	50 l/min
<i>pump diameter</i>	3/4"	3/4"	1"	1"	1 1/2"
Output at 20 m head	12 l/min	12 l/min	20 l/min	20 l/min	25 l/min
<i>pump diameter</i>	1/2"	1/2"	3/4"	3/4"	1"
Output at 30 m head	-	-	12 l/min	12 l/min	16 l/min
<i>pump diameter</i>	-	-	1/2"	1/2"	3/4"
Cost ex-factory	US\$ 450,-	US\$ 480,-	US\$ 700,-	US\$ 750,-	US\$ 780,-

Table 4.1 The different windpump models in production by workshop Aerobombas de Mecate in Managua (AMEC). The output figures are based upon the documentation provided by the manufacturer, for a wind speed of 5 m/s.



Examples of the three types of AMEC windpumps.

Upper left: H-360

Upper right: H-270

Bottom right: H-8



4.2 Description of Main Components

The AMEC rope windpump is built up of six main parts:

- a four- or six-bladed rotor
- the safety mechanism with hinged vane
- the rotor head to adjust to the wind direction
- the transmission
- the tower, consisting of three legs
- the rope pump

In the following sections, these elements are described in brief; a more detailed explanation can be found in [16].

4.2.1 The Rotor

All models have an upwind horizontal axis rotor made from steel spars that are welded onto the tubular rotor shaft. The six rotor blades are made from galvanised steel sheets with a curvature of 10% of the chord length. The chord is constant and the blades have a small linear twist. A remarkable feature of the rotor is that the rotor blades cover only the outer section of the total swept area. By consequence, the construction is very light and gives a torque high enough to drive the rope pump. However, the power efficiency coefficient (C_p) is rather low and is estimated at approximately 0.13 [24].

The blades are bolted to steel supports on the rotor spars, which are welded to the rotor shaft. The spars are reinforced near the rotor axis with angle bars and tension rods to give sufficient structural strength to the rotor. The smaller H-8 model has 4 blades; the other models have 6 blades.

4.2.2 The Safety Mechanism

The tail is made of a welded truss of steel tubes, while the vane is made of standard corrugated sheet steel, which gives it more stiffness than a plain sheet.

The "hinged vane" safety mechanism turns the head out of the wind in higher wind speeds. If the rotor turns more than 270 degrees, the transmission rope touches the tower, runs from the pulley and falls down. The system stops pumping and the rotor turns freely and unloaded. In high winds, the rotor speed is limited by the safety system. In case of the *multigiratorio*, the rope stays in place and the system keeps functioning.

4.2.3 The Rotor Head

The rotor head holds the main shaft with the rotor and is offset from the axis of orientation. The transmission pulley is at the other side end of the rotor shaft. The arm for the "hinged side vane" is fixed to the rotor head frame.

The rotor head consists of a welded triangular assembly of angle irons and a vertical tube that rests on the yaw bearing of the tower (allowing the rotor to orientate itself into the wind). The yaw bearing consists of a pipe filled with oil and absorbs the vertical thrust of the head.

4.2.4 Transmission

The rotor drives the pump via a polypropylene rope that runs in a loop over a pulley mounted on the back-end the rotor shaft, and another pulley mounted on the pump shaft. The yawing movement (rotation) of the rotor head causes a "pulling force" on the rope, as this has a fixed length. The required flexibility is introduced by using a "Chinese" sleeve bushing at the pulley end of the pump shaft. If the rotor turns out of the wind, the pump shaft is slightly lifted upward by the rope, enabling a free movement of the head of 270°.

The other function of the "Chinese" bushings is that the rope is automatically kept under tension by the weight of the shaft and pulleys. When pump load increases, the rope tension also increases and slipping is avoided.

The downward rope of the *multigratorio* is led -via a third, small pulley- through a vertical pipe located at the centre of the tower to make possible a maximum rotation of the head of 360°.

The four bushings for the rotor and pump shaft are made of hard wood available in Nicaragua. The bushings are soaked in oil and boiled for some hours. Since the rotational motion of the shafts is slow and high peak loads do not occur, the wood performs well. The use of wood for this purpose has been studied more in detail a.o. by the "Werkgroep Ontwikkelingskunde" of the University of Twente (WOT) [17].

AMEC mentions a number of advantages of wooden bushings compared to ball bearings. They are not only cheaper and easier to maintain, but also are less critical and have an "integrated alarm system". When they run dry, the shrieking sound warns the owner that he should add some oil, but the wood is not damaged. A ball bearing generally does not make any noise -until it is too late and has become irreversibly damaged.

The freely accessible pump shaft can also be connected to any other automotive device in case there is no wind. Possible options are a motor cycle, a car, an electric motor or human arm or leg force. The other way around, the rotating pump shaft can also be used to provide input power for grinding mill, or to drive an electric generator.

4.2.5 The Tower

The 3-legged tower is welded together from angle bars and round tension rods. The side with the transmission pulleys and rope is flat and vertical with the pulleys in the middle of (and above) the well. The flat side also facilitates the assembly. The other two legs of the tower are slightly curved and give it a rather elegant impression; the total weight is not more than about 100 kg (for the H10-270). The foundations for the tower are made out of heavy angle bars with a reinforced cement base and are pre-fabricated. The foundations are lowered in three dug holes and covered with stones and sand. No additional cement is used for the foundations on location, which makes it possible to install a rope windpump within one day.

4.2.6 The Pump

The pump is basically the same as the rope hand pump. The pulleys on the pump and rotor shaft are made of used car tires and a steel support structure. The pump pulley is bolted onto a pump shaft

made of a galvanised pipe. By mounting different sizes of pulleys, the pumping capacity can be improved, e.g. by using a larger pulley in the windy season and leaving the pump size unchanged. Different pump diameters are used ranging from ½" to 1 ½" as can be derived from the Table 4.1. Just as in the case of the rope handpump, the downhole parts of the rope windpump are many times lighter than those of a traditional windpump. This difference can be as high as 12 times and brings along important advantages in maintenance practices and costs.

4.3 Installation

For installation, the windpump is transported in parts on a normal station wagon or pick-up van. The AMEC rope windpump can be easily installed without special or heavy equipment such as tackles or winches. Four people must co-operate during erection of the tower, to hold the ropes. Two persons can do the whole installation within half a day, provided that the holes for the foundation have been dug in advance.

4.4 Operation & Maintenance

The manufacturer's product leaflet states that the rope windpump requires daily attention. This important aspect is stressed again in a purchase contract between the owner and the manufacturer. The user is supposed to frequently check its functioning and readjust the tension of the transmission and pump rope if necessary. For this purpose, AMEC provides the required information in its maintenance manual [28]. Especially if the transmission rope is new, adjustment may be necessary several times a week. If the rope or pistons are worn out, they must be replaced. With a bit of practice, this is not difficult and can be done by the user, without the need to remove the pump from the well. All the tools required for this maintenance and small repairs are an oil can, pliers and a spanner no. 14.

Regular maintenance includes also a general check of the pump and the transmission on wear and tear, lubrication of the bushings with a few drops of oil, and painting of corroded parts if required.

Under certain wind conditions, the transmission rope falls off. Then one should first (for safety reasons) stop the rotor by turning it out of the wind, climb the tower and put the rope into place again. The Nicaraguan rope windpump is installed facing the locally prevailing northeastern wind direction. If during some days the wind direction is very different (from the southwest), the transmission rope tends to come off frequently. It is then up to the user to reposition it several times a day or decide not to use the windpump under these circumstances.

4.5 The Rope Wind Pump-Battery Charger

AMEC has installed two rope windpumps equipped with a permanent-magnet electric generator, driven by a rope and an additional pulley on the pump shaft. The idea is to create a system that can satisfy two basic needs for the rural area, water and electricity. It delivers a rectified DC current for charging a battery to provide electricity for lighting, radio and television. It is directly connected to a car battery without a charge controller or protection against overloading and deep discharging. The generator has a maximum capacity of about 150 W and is imported from China.

AMEC has also developed a separate windcharger based upon the rope windpump technology. This windmill has a 2-m rotor and drives a cheap DC commutator machine with permanent magnets imported from the United States [18]. The system has been in operation in Cofradía (near Managua) and provides current for three lights, a radio and a B&W television. The user charges the batteries for four neighbours with the surplus electricity, and has installed the electric wiring in their houses.

5. END-USE OF THE ROPE WIND PUMP

5.1 Classification of End-users

In order to collect information about the operation, application and economy of the rope windpump and the attitude of the users, an end-use survey was carried out from 25 March till 16 April 1998. During the end-use survey, it was found that the users and/or owners of the rope windpump could be classified into three main categories: cattle holders; small farmers; and "special cases". Altogether, 28 rope windpumps were visited during the survey. The corresponding owners were divided over the several categories as shown in Table 5.1.

CLASSIFICATION OF END-USERS				
	people visited		water needs	business characteristics
cattle owners	16	57%	cattle watering	commercial; high income; delegated administration, contracted labour
small farmers	8	28%	multiple	traditional subsistence; low income; family labour
"special cases"	4	15%	multiple	leisure or business; high/middle class income; contracted labour
Total	28	100%		

Table 5.1 Distribution of the 28 rope windpump visited during the end-use survey [19] according the category of owner: cattle farmers, small farmers, and "special cases".

The choice of the visited windpumps was not ad random. Besides practical arguments and certain budget limitations, the following selection criteria were used:

1. to visit at least one unit of all four existing models of the rope windpump
2. to visit a significant number of rope windpumps located far away from the manufacturer, to evaluate maintenance and after-sales aspects
3. to review a variety of applications of the rope windpump

5.1.1 Category I: Cattle Owners

Cattle owners represent an important market segment for commercialisation of the rope and washer windpump. Historically this was the first group in Nicaragua that used windpumps (of the American type). This category represents a commercial market for the rope windpump manufacturer AMEC. The cattle farmers are relatively wealthy and able to buy a rope windpump out-of-the-pocket, or sometimes by apply for a short-term credit. For this group of owners, the rope windpump is considered as one possible option out of a number of different pumping alternatives. The criteria to choose a rope windpump are economy, reliability, and convenience. The rope windpump is generally operated by an operator, not by the owner.

The survey team visited 16 people belonging to this group who in some cases have 2 or 3 windpumps. The number of cattle varies between 60 to 300 heads, which gives an estimated water demand of 2.4 to 12 m³/day (assuming a consumption of 40 litres/day per head). Such small water volumes are easily pumped by the rope windpump. Storage capacity is generally present to cover a 3-4 day water need. Some owners have employed more than one operator.

5.1.2 Category II: Small Farmers

The activities of the group of "small farmers" are directed to subsistence rather than business. In general, these people have little or no money to buy a windpump and need some kind of financial help to acquire one. They can benefit from a windpump to have access to more water with less effort, which can be used to increment crop production, for watering of some heads of cattle, and for the homestead. For this group, a rope windpump may be an important asset for income generation, while the increased availability of water may improve the sanitary conditions for the farmer and his family.

In general, these farmers have benefited from some agricultural re-structuring or land redistribution programme and are often addressed by some co-operation programme or project. Not all "small farmers" have a long tradition in agriculture, as partly they come from other sectors, such as the mines or the army. The land extensions vary between 0.5 and 15 "manzanas" (3,500 to 105,000 m²; 1 manzana = 7,054 m²).

The project team visited 8 small farmers as described in detail in [19]. All people have obtained the rope windpump through some financing programme. The land areas vary between 2 and 7.5 manzanas with one (exceptionally large) area of 13 manzanas. The user of the rope windpump is always the owner. The applications of the pumped water are multiple: domestic use, some cattle watering, and small-scale irrigation. The volumes of water pumped are from 4 to 7.5 m³/day throughout the year. This implies that the windpumps are heavily under-exploited. Most farmers use the windpump only during a few hours, after which they stop it.

5.1.3 Category III: "Special Cases"

The group "Special Cases" consists of people who do not generally depend on their farm business. They have appointed a tenant farmer that lives with his family at the farm and operates the windpump. The owner often experiments with crop and cattle growing, which makes an analysis and comparison less straightforward. The windpump is generally perceived as an external input to the farm business and considered "free" -once the windpump has been acquired. This extra asset for water supply has an important impact on the farm production and thus is quite appealing.

5.2 Use of the Water

The water provided by the rope windpumps serves three main purposes:

- domestic use
- cattle watering
- irrigation

In some rare cases, one can observe fish farming (tilapia) in the water tanks used for irrigation.

5.2.1 "Patio-Use" and Beyond

An important aspect of water use among category II (small farmers) is the so-called "patio-use" as described in [20]. Most farms in Nicaragua have a homestead or "patio" around the house, which is distinguished from the larger "parcela", the production plot. In general, the "parcela" is the domain of the man, the "patio" the territory of the woman.

They both have their own characteristics; they are used differently, and require different inputs and provide different outputs. One can not isolate one from the another: both are interrelated and subsystems of a larger production system: the farm. Together they are geared towards the main objective of the farm: how to secure food and income for the family.

The application of water at the patio is varied and includes three main purposes:

- domestic use:
 - a) drinking water
 - b) washing & laundry
 - c) kitchen
- cattle watering:
 - a) poultry, ducks, goose
 - b) small animals such as such as goats, sheep, pigs
 - c) a few cows or horses
- irrigation:
 - a) fodder crops
 - b) fruit trees
 - c) vegetables
 - d) herbs

The small amounts of water involved can to a certain extent be supplied by a handpump as well [20]. The application of water "beyond the patio" for cattle and irrigation requires larger volumes, which are more readily supplied by a rope windpump than with a handpump

6. THE POSITION OF WORKSHOP AMEC

6.1 AMEC and CESADE

The non-governmental organisation CESADE "Centro de Estudios y Acción para el Desarrollo" works in rural development programmes for the "dry tropics" of Nicaragua. Part of these programmes is the promotion of low-cost technologies, among others the rope handpump and rope windpump technology. To this end, CESADE supplies credits and technical assistance for development, production and implementation. It is supported by a Dutch expert, Henk Holtslag, from DOG/PSO in the Netherlands.

Workshop Aerobombas de Mecate (AMEC) in Managua started in 1990 -at the termination of the SNV/IMEP wind energy project- as Workshop López to develop and produce low-cost sustainable technology. It was an initiative of the advisor in this project, Mr. Henk Holtslag, and his Nicaraguan colleague Mr. Luis Román. The latter is still the present director of AMEC. In 1991, the workshop received certain financial and technical support from SNV. Since 1994, the Dutch organisation DOG/PSO has actively supported the work of AMEC by financing Henk Holtslag to continue his activities, now from within CESADE.

The combined effort of a non-governmental organisation and a private company with external technical support has proven to work out well.

6.2 Company Profile of Taller AMEC

Taller AMEC ("Aerobombas de Mecate") in Managua is practically the only manufacturer in Nicaragua that produces, distributes and installs the rope windpump on a commercial scale. It is basically a small but sound business, which offers a whole range of products for water pumping, including the common rope handpump. At their premises in Managua it has an excellent demonstration site showing all the developed technologies.

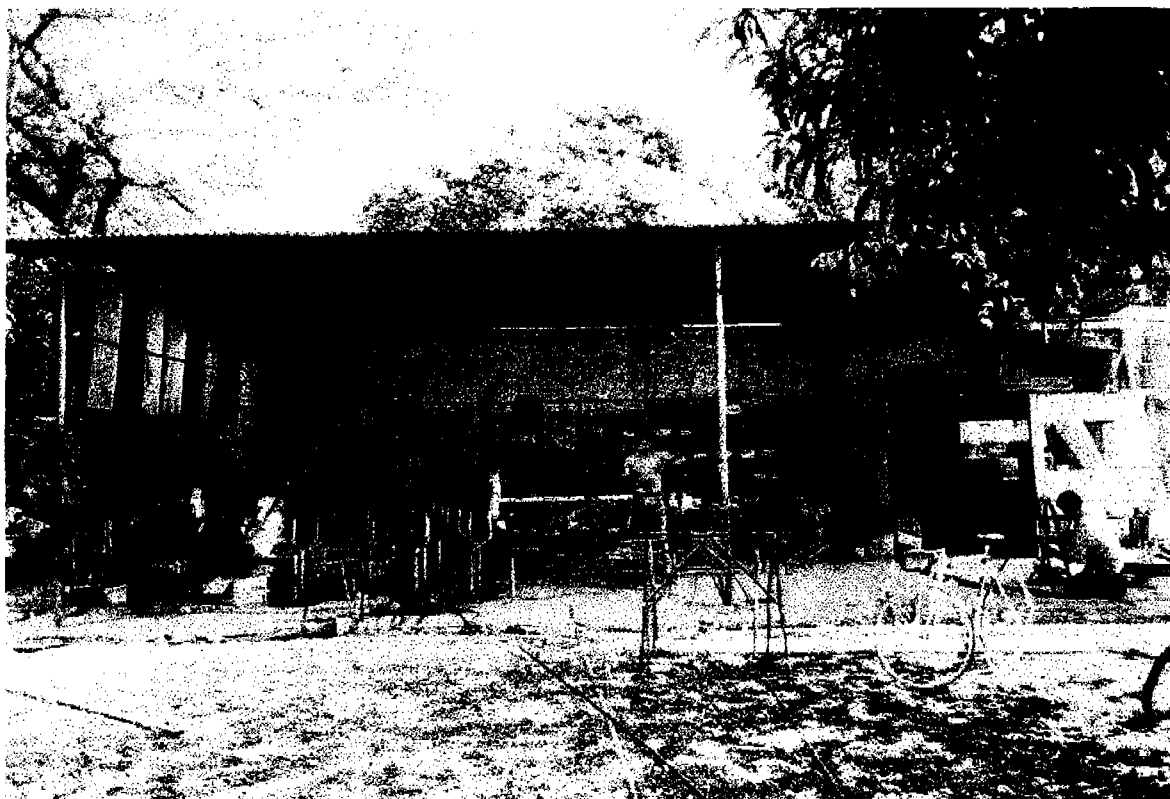
The fixed working staff consists of 3 persons, including the director who performs all roles if required, from workshop manager to salesman. At the moment two part-time workers are engaged. The current production of windpumps is about 24 units per year.

Currently, the company has a good order portfolio and has built up sufficient own capital to be independent from bank loans.

6.2.1 Product Range

Apart from the rope windpump models, AMEC produces rope handpumps and a "do-it-yourself" version of the rope handpump: the "Bomba de Mecate kit". This has been an in-house development of AMEC following the recommendations of the handpump evaluation by IRC [1]. AMEC has also developed other "extensions" of the rope pump, such as the animal traction pump (as described in section 4.1), and has started production of a small wind battery charger.

Apart from the production of pumping equipment for water supply, AMEC performs well drilling, using a self-made drilling device constructed around a Deeprock drive imported from the USA.



Front view of the AMEC workshop

6.2.2 Production Facilities

The total area used for production of these windpumps is 224 m² (including storage). The equipment presently in use for the production is:

- two welding machines
- two drilling machines
- a guillotine shear
- several small tools

The value of the tools (present new price) is about US\$ 4,500,-.

6.2.3 Sales Figures, Pricing and Promotion

The sales figures of the rope windpump models over the last years are shown in the Table 6.1.

Year	Model	H-8	H-10	H-12	Total
90			1		1
91		2	1		3
92		1	7		8
93		1	9		10
94			15	3	18
95		2	16	2	20
96		1	9	1	11
97			6	15	21
98 (first quarter)			1	4	5
Total		7	65	25	97

Table 6.1 Sales figures of different types of the rope windpump produced by Aerobombas de Mecate (AMEC) in the period 1990-1998.

From the start in 1992 up to now, approx. US\$ 4,000,- to US\$ 5,000,- has been spent on promotion, visiting fairs, etceteras. This figure is about 5 to 7 % of the total windpump turnover.

6.3 Other Manufacturers of Rope Windpumps

Two other workshops in Nicaragua have produced copies of the AMEC rope windpump, but they were not very effective. One manufacturer, also in Managua, has produced one rope windpump that is still functioning after 3 years, although its tail has broken. This replica, with a rotor diameter of 3 m, was offered for a price of US\$ 1,200,-.

The second manufacturer is based in Rivas and up to now has built 3 machines, but seems to have suspended the production. These machines were visited during the end-use survey and although they were not very elegant, they were all functioning.

6.4 Production Potential and Limitations

Since AMEC is the only manufacturer of rope windpumps with a substantial and regular production, one can hardly speak of the existence of a (rope) windpump manufacturing sector in Nicaragua. As a result, the position of the rope windpump in Nicaragua is still rather vulnerable.

According to Luis Román, his personnel also needs training in technical skills, administrative aspects and managing of work. Neither the director, nor his employees have sufficient theoretical knowledge of the design and functioning of a windpump, which will be an obstacle for future product development.

At present, it is premature to recommend the production of the rope windpump by a second company in Nicaragua. AMEC is able to increase its production to about 60 windpumps per year, in addition to its other products. Bottlenecks at that rate of production would be the available workspace and equipment. The production of some parts can be subcontracted to other workshops.

A rough indication for a potential windpump market of about 3,000 units in Nicaragua is given in [7].

7. FINDINGS ON PRODUCTION AND DESIGN

7.1 Production and Design Philosophy

The AMEC rope windpump has been designed for manufacture in simple workshops, using elementary equipment: lathes or milling machine or foundry are not required. Production practices do not aim at large numbers but at small batches or one-off products. Preference is given to the input of human labour instead of the use of capital intensive equipment.

The production of certain components, such as the tires for the pulleys and several basic parts for the structure, is subcontracted.

For a number of components such as the rotor assembly, jigs are used. This improves the quality of the products and reduces labour time. The goal to produce the rope windpump with simple equipment in a basic workshop has certainly been achieved. There is still room for improvement in the quality of the work, in particular with respect to maintaining a constant quality.

7.2 Cost Breakdown of a Rope Windpump

The Table 7.1 gives a breakdown of the cost of an H-10 rope windpump.

COST BREAKDOWN OF THE AMEC ROPE WINDPUMP H12-270	
material cost	US\$ 250,-
labour cost	US\$ 87,-
administration, equipment, overhead, watchman	US\$ 192,-
profit and risk	US\$ 200,-
Total cost ex-factory	US\$ 700,-
transport & installation	US\$ 200,- to US\$ 300,-

Table 7.1 Cost breakdown of the AMEC rope windpump. Required labour time to produce one windpump is 15 man-days of 10 hours, thus 150 man-hours. Average costs per man-day are US\$ 5.8,-. The transport costs shown are for a distance of 60 km from the manufacturer in Managua.

7.2.1 Annual Maintenance Costs

The annual maintenance costs during the survey were found to be approximately US\$ 28,- per year for a "normally maintained" machine. The people interviewed mention the following actions for maintenance:

- periodical change of the ropes and pistons
- lubrication by adding some oil

It should be noted however that most of the users have had the windmill only for a few years, and maintenance costs might increase with the lifetime of the machine.

AMEC's director Luis Román gives a figure of US\$ 50,- per year based on an estimate of the maintenance required to secure a lifetime of the windpump of at least 15 years; this includes, for instance, preventive actions such as painting of the windmill every 5 years.

7.3 A Comparison with the Chicago Aermotor

In this section a comparison is made between the rope windpump and the Chicago Aermotor with respect to production methods and machinery needed for manufacturing, installation and maintenance. Table 7.2 gives an overview of the most important characteristics of both machines.

COMPARISON OF THE CONSTRUCTION		
	Chicago Aermotor	Rope Windpump H-12
<i>Technical data</i>		
rotor diameter	3 m	3.60 m
Gearbox	yes	No
max. pumping head	85 m	50 m
<i>Weight</i>		
Head	302 kg	52 kg
tower (10 m)	268 kg	101 kg
pump including rising main	more than 100 kg (depends on well depth)	10 kg
total weight	670 kg	163 kg
Nominal capacity (pumping head 20 m; wind speed 8 m/s)	approx. 1 l/s	Approx. 1 l/s
Lifetime	over 20 years	12 – 15 years
Total cost ex-factory	US\$ 5,000,-	US\$ 780,-

Table 7.2 Comparison of some important construction features of the Chicago Aermotor and the rope windpump H-12 to give an impression of the complexity of both machines. It is clear that the rope windpump has a much lighter construction, which is reflected in a significantly lower investment. The lower weight of the downwell parts greatly facilitates pump maintenance and related costs. The low total weight also has a strong positive impact on transport and installation of the rope windpump. On the other hand, the Aermotor has a longer lifetime and can pump water from very deep wells.

COMPARISON OF PRODUCTION METHODS		
	Chicago Aermotor	Rope Windpump H-12
<i>Required production skills</i>		
lathing	•	
milling	•	
casting	•	
welding	•	•
drilling	•	•
cutting (with guillotine shear)	•	•
sawing	•	•
grinding	•	•

Table 7.3 Comparison of required production skills for the production of a Chicago Aermotor and a rope windpump H-12. Techniques requiring expensive machinery (lathing, milling and casting) are not needed in the case of the rope windpump.

The production methods and skills for both machines are stated in Table 7.3. Table 7.4 summarised the efforts required for installation and maintenance.

Compared to the "American" type windpumps in use in Nicaragua, one can easily see the huge difference in complexity and weight of the structure. The rope windpump is about four times lighter, which is reflected in the much lower investment costs. The rope windpump is also easier to produce, without the need for lathes, milling machines or foundry. However, the "American" windpumps are expected to have a longer lifetime, and are of a more versatile concept.

COMPARISON OF INSTALLATION, OPERATION & MAINTENANCE		
	Chicago Aermotor	Rope Windpump H-12
<i>Installation</i>		
heavy equipment needed	tackles, winches	none
concrete required	Yes	no
time involved	several days (up to 1 week)	4 hours
<i>Operation</i>		
attendance	None	daily
time involved	None	less than 2 hours per day
<i>Pump maintenance</i>		
heavy equipment needed	tackles, winches	none
execution	maintenance experts	user
time involved	one day	one hour
costs per year	US\$ 300,- to US\$ 500,-	US\$ 25,- to US\$ 50,-

Table 7.4 Comparison of required installation, O&M of the Chicago Aermotor and rope windpump H-12. The item "pump maintenance" refers to the annual replacement of the leather cup or piston owing to normal wear and tear. It is seen that the recurrent (maintenance) costs for the rope windpump are much lower than for the Chicago Aermotor, which is determined completely by the difficult and costly lifting of the pump by a professional maintenance team. On the other hand, no costs are attributed for the time spent by a user for daily attendance of the rope windpump. These costs are assumed to be low for the market segment that uses the rope windpump.

7.4 Overall Impression of Reliability in the Field

During the evaluation mission and the end-use survey altogether 35 rope windpumps installed in the field were visited, which is about one third of all the machines installed by AMEC). Of this number, 23 were found operational.

Of the 12 windmills that were out of service, 7 systems were not used anymore because of a variety of reasons:

1. there had been a change of land activities and/or owner (2 cases)
2. the windpump was stolen (1 case)
3. the user did not use the windpump anymore because he was not satisfied with it (3 cases)
4. the design was modified by the owner (1 case)

The reasons given under (1) and (2) are external and difficult to attribute to a failure of the windpump itself or its acceptance by the user. Therefore, it seems reasonable to subtract these 3 machines from the total visited (35) and obtain a corrected number of 32 units for the machines in principle available to the user. The reasons (3) and possibly (4) indicate a dissatisfaction of the user (4 cases), which motivated them to abandon the machine. The 5 other windpumps that were found out of service did not work due to some kind of technical failure.

Altogether, one finds that 23 out of a total of 32 machines (excluding the cases due to external reasons) were in service. This is a score of approx. 72% for the percentage of windpumps that was effectively used.

To evaluate a percentage score for the windmills that were technically functioning, first the number of windpumps is established that potentially could be operating. This number is equal to the total (32) number minus those machines abandoned by the owner (4), which are 28 units. Of this number, 23 were working, equivalent to about 82%.

One should make an annotation to these figures. As the number of windpumps visited is very small (even the total number of installed rope windpumps is small), one should be very cautious to perform any statistics on the basis of such a limited data set. One might try to correlate aspects such as technical functioning and user acceptance as they are probably related, but it is hard to quantify. Therefore, an overall impression of the reliability in the field is more readily expressed in the form of a general statement: "of the rope windpumps visited in the field, about three quarters is operational and effectively used"

The score for "technical functioning" is about four out of five machines. This is quite a good figure as the survey included a number of units of an older version that still had certain design imperfections. Covering only the latest, mature versions of the rope windpump, this score would have been significantly higher. One may therefore conclude, that the current AMEC rope windpump is technically reliable and not likely to fail if maintained correctly.

The mission identified some problems with the older machines such as the weak connection point of the vane arm (which caused several vanes coming down) and the blade support structure (leading to cracks in the blades). The worst case reported during the development process of the rope windpump concerns an entire rotor coming down. At that time only one bolt was used to fix the pulley onto rotor shaft. After the incident, the number of bolts was doubled and no more rotors fell off [21].

The survey detected some minor problems with the multigiratorio, regarding the yaw bearings and the transmission pulleys. Of the multigiratorio windpump, only 5 have been built and installed so it is too early to conclude that the product has already reached maturity.

In general terms, the rope windpump technology is found to be reliable under Nicaraguan conditions.

7.5 Attitude of the User

The cattle owners and operators state that they are very satisfied with the rope windpump. Curiously, they do not recognise that the problem with the transmission rope (which falls off if the wind direction changes more than 135°) is inherent to the design of the AMEC rope windpump. If asked, they say that this is a "design error", as they compare this machine to a traditional, imported windpump (and expect it to behave identically). Apparently, at the moment of purchase, they are not fully aware of this limitation.

Most small farmers (five out of eight) state that the windpump is "trustworthy and easy to use" and that they are happy with it. Sometimes they call it the "papalote de mecate" or their "modern" windpump, which shows that they appreciate it highly.

7.6 Reliability of Components

7.6.1 Transmission

Users report that in a number of cases the transmission rope gets entangled between the two tire halves that make up the pulleys. This occurs when the tension on the rope increases (due to the rotor head turning out of the wind in higher wind speeds). Further, the rope of the transmission gradually gets worn and has to be replaced about 3 times per year.

7.6.2 Bushings

The wooden bushings perform very well from a technical point of view and in none of the installed machines did they need to be replaced. Therefore the choice of wooden bushings has certainly been appropriate.

7.6.3 The Rope Pump

Most users report that they have to replace the rope of the pump 3 times a year, while the pistons need replacement once a year [22]. Various people (a.o. Alberts [27]) comment that the pistons of the rope handpump last much longer, as they are of a better quality than the ones used by AMEC for the rope windpump. Also some tube sections may need to be changed once in a while.

7.7 User Operation and Maintenance

The Nicaraguan rope windpump is easier to handle than a traditional windpump, but cannot be left unattended and it requires more maintenance. Only people who dare (and are able) to climb the tower can keep it running. Two people (an old man and a heavy person who could not climb) had to appoint somebody else to operate it. Women do not climb the tower and rely on their husband for operation, or need to contract an operator.

Sometimes the transmission rope must be put in place three times per day; the frequency of occurrence depends on the variability of the wind. Some users complain about this, but nevertheless

keep using the rope windpump. Although they sometimes feel it as an inconvenience, they accept it as an unavoidable task. In general, users are very happy with the windmill.

Another problem is that the transmission rope may be stolen during the night; this is why people do not use the windpump at night and sometimes remove the rope.

In many cases encountered, the users attach the rope of the vane arm to a tree or a pole "to control the rotor". The head of the machine is left in a fixed position, even overnight. This is very dangerous because the rotor cannot move out of the wind if a high wind speed occurs; it catches the full thrust of the wind and may break. Several vanes have broken off and occasionally some blades have flown off. The lower hinge connection seems to be the weakest part of the tail construction and is most likely to break.

7.7.1 Safety

The rope windpump is much more a device that can be handled on a "human scale" than the first-generation machines, and no accidents have ever been recorded among the end-users. This may illustrate that it is a relatively safe device.

7.8 Technical Performance

As part of the evaluation of the rope windpump, a measuring programme was carried out. The experiments consisted of a series of "short-term" and "long-term" measurements, which are described in detail in [23] and [24]. The "short-term" measurement programme took place from 24-28 March, 1998 on two H-12 rope windpumps at the *Carretera Vieja a Leon*, one ("A") at the *Quinta Alejandra* (Km. 33), the other one ("B") at the *Escuela Simiento* (Km. 40). The objective was to determine the technical output, efficiency and availability of the system in dependence of the wind speed.

The "long-term" measuring programme extended into the rainy season and aimed at collecting data on the long-term output of the rope windpump in the field. It included recording of the daily average wind speed, as well as observations with respect to downtime due to repair or failure, and application of the pumped water by the user. It was started in April and finalised at 18 July. This programme was hampered by low wind speeds and did not provide much useful data. The lack of wind was especially felt since both test windmills were equipped with a large pump, and most of the time did not produce any water at all. The measurements at site "A" at the *Quinta Alejandra* interfered with the agricultural practices of the farmer. In a later stage, they were continued on a new site "C", the farm of Mr. *Francisco Saenz* (Km. 37.5, Ctra. Vieja a Leon), but these measurements did not provide the desired information either. In general, long-term output measurements require a much longer period of observation than available in this project.

The number of data obtained during the "short-term" programme is quite small as well and definitely not sufficient to draw hard conclusions on the performance of the rope windpump. However, they give interesting indications of the system performance, pump behaviour and coupling of components.

The water output of the H-12 windpump "A" at the *Quinta Alejandra* as a function of the wind speed is shown in Figure 7.4 together with the system efficiency ("from wind to water"). This curve is typical for a mechanical windpump, with a pronounced peak in efficiency of about 8% at a wind speed of about 5.8 m/s. This wind speed, where the system reaches its maximum efficiency, is called the *design wind speed*. The system starts pumping at a wind speed of about 4.2 m/s, which is called the *starting wind speed*. The ratio of the design and starting wind speed is approx. 0.7, which is a common

windpump of these dimensions. The design wind speed is rather high and is a result of the combination of a large pump connected to this rotor. This aspect of the rope windpumps has been discussed previously and is confirmed by the measurements. At higher wind speeds (above 7 m/s) the efficiency drops quickly, as the safety mechanism increasingly turns the rotor out of the wind.

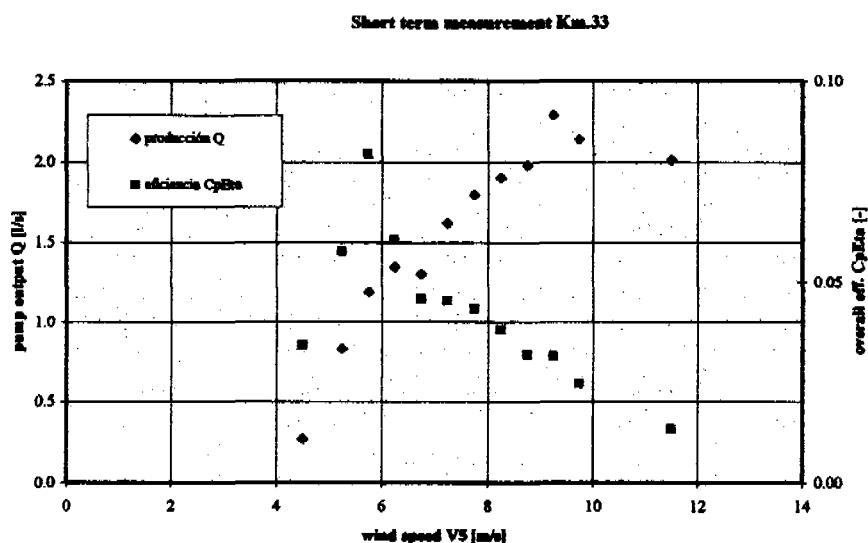


Figure 7.5 Output and efficiency of the H-12 rope windpump as a function of the wind speed. The found output and efficiency curves are typical for a mechanical windpump. The optimum efficiency is about 8% at $V=6$ m/s. The measurements are carried out in March 1998 at site "A", the Quinta Alejandra, Km. 33 Ctra. Vieja a Leon [24].

The "short-term" measurements also provided interesting information on the behaviour and volumetric efficiency of the rope pump. It was found that the maximum volumetric efficiency is about 90%, but decreases rapidly below a certain speed of the pump rope. Apparently the rope speed should be chosen sufficiently high to guarantee a good volumetric efficiency. As an analysis of the pump characteristics is beyond the scope of this project, a detailed description of this aspect is deferred to [49].

The "short-term" measurements at site "B" provided only very limited data and can be found in [24]. The wind speeds during the test period were extremely high (above 8 m/s).

7.8.1 Long-term Output

It is tried to estimate the long-term output of the H-12 rope windpump at site "A" and compare it with that of a 3 meter diameter Fiasa 10/40 windpump. This machine is a copy of the Aermotor produced in license in Argentina and has been subjected to extensive measurements by CWD in 1985/86 [25].

The yearly output is found by multiplying the available power at a certain wind speed (as defined by the power curve of both machines) with the expected number of hours per year that this wind speed occurs, and repeating this procedure for all wind speeds. The result is the total amount of water pumped during one year. The expected occurrence of wind speeds during the year is dictated by the frequency distribution. For the calculation, the so-called Weibull distribution is assumed.

The calculated yearly output depends on the yearly average wind speed and the Weibull k -factor that determines the type of wind regime. By dividing result by the number of days in a year, the average

The calculated yearly output depends on the yearly average wind speed and the Weibull k -factor that determines the type of wind regime. By dividing result by the number of days in a year, the average output per day is obtained on a long-term basis. This output is presented for both machines in Table 7.6 in relation to the annual wind speed, taking the Weibull k -factor equal to 2.

COMPARISON LONG-TERM OUTPUT FIASA 10/40 AND H-12 ROPE WINDPUMP				
wind speed	FIASA 10/40		H-12 measured	
<i>m/s</i>	[kWh/day]	[m ³ /day]	[kWh/day]	[m ³ /day]
3	0.58	214	0.31	115
4	1.00	364	0.81	299
5	1.35	495	1.32	486
6	1.63	597	1.73	635
7	1.81	666	2.01	736

Table 7.6 Comparison of the long-term average output of the FIASA 10/40 and the H-12 rope windpump based on a theoretical model. The annual output is calculated and divided by the number of days per year to give the average daily output on a long-term basis (in kWh/day and m³/day). The output figures given are for a Weibull distribution with shape factor 2. It should be noted that reductions in output due to downtime are not included, nor any judgement on the effectiveness of the water pumped. The given figures for the H-12 rope windpump are based on the output curve of determined at site "A" at Km. 33, Ctra. Vieja a Leon.

The purpose of this exercise is to give an estimate of the expected output of an H-12 rope windpump compared to that of a Fiasa 10/40 (or Aermotor) classical windpump. Ideally, such a comparison should be based on long-term observations of a significant number of windmills in the field, but such empirical data are not available for the rope windpump in Nicaragua. One should also bear in mind that the precision of the determined output curve for the rope windpump (Figure 7.5) is not very high, which poses an additional limit to the accuracy of the presented comparison.

The presented theoretical estimate does not include the effects of system downtime due to repair, failure or user limitations, and does not reveal information about the usefulness of the water pumped. These effects should be included for a true comparison of both systems, and to determine the cost and value of the pumped water. An empirical estimate of the value of the water pumped would also include a judgement on the availability of both machines, which is not covered by this output analysis.

For the time being, Table 7.6 shows that the output of both systems is comparable. It is seen that the H-12 rope windpump has less output than the Fiasa if the annual wind speed is low, and performs slightly better at higher wind speeds (above 5 m/s). This is due to the fact that the Fiasa was equipped with a relatively small pump and starts producing water at less than 3 m/s, while the H-12 rope windpump at the Quinta Alejandra drives a large pump (1.5" tube) and starts at only 4.3 m/s. Once the wind is strong enough to turn this windmill, it produces large amounts of water however.

From the end-use survey it has become clear that the windpumps are generally under-exploited: the users do not strive for a maximum water production during the day, but shut off the windpump as soon as they have "enough water". Due to this under-exploitation, the chosen pump-rotor combination and the downtime are not critical. The wind regime in Nicaragua (in the dry season) guarantees a number of hours with strong winds every day, so that maintenance can always be scheduled outside that period. If the rope windpump is used more intensively, these factors will have

an increasing influence on the total output and availability.

7.9 Repair and After-sales Service

In a number of cases, replacements of parts and eventually some technical support is needed, for example when parts of the windpump are stolen (sometimes even the complete pump!), blades have been damaged by the user; or the rope has been damaged by sticking between the two tire halves that make up the pulleys. These problems are not easily addressed by AMEC, especially if they occur in remote areas far from Managua; a properly trained local technician with a small workshop would probably handle them more adequately. If the windpumps are used for cattle watering, the maximum allowable downtime is very short, i.e. the windpump should be repaired within one day. This is certainly an aspect that requires improvement.

7.10 Findings on the Rope Wind Pump-Battery Charger

During the mission, it became clear that the present rope windpump-battery charger is only a first try-out. One of the users visited had created an alternative system: a jeep, with one wheel driving the shaft of the rope pump, to which he had connected pumps, tools and also the generator! The owner explained that a few times per week, he let the jeep run for about one hour and a half.

The dual mode (water/electricity) of the system adds to the complexity of operation. Currently, the user operates the rope windpumps during a limited number of hours per day. In order to charge a battery the windmill must run almost all the time that there is wind available. If the system is used to charge a battery while it is pumping water, there will be little energy left for the battery and the user will complain that the batteries are not charged. The solution would be to teach the user to use the windmill alternatively as a water pumper or as a battery charger (and not simultaneously).

A system that provides both water and electricity is certainly worth further development. The imported Chinese permanent-magnet generator costs in Nicaragua about US\$ 200,- which is rather expensive. Including the transmission, the extra costs (compared to the standard windpump) are roughly US\$ 300,-.

The small windcharger seems to perform technically well; also the user is quite satisfied. The mission found that the system installed at *Cofradía* in May 1997 was functioning without any problems (and according the latest information (May 1999), it seems continuing to work well). There are now plans to build some more units and install and monitor them. The lifetime and reliability of the used generators is unknown. (These are commutator machines and the brushes may wear out fast, especially if the load current is too high.) The generator and transmission are considered the most critical parts of the design but have performed beyond all expectations. The positive response that AMEC has received encourages continuing development of this system.

8. INSTITUTIONAL SUPPORT ORGANISATIONS

8.1 Governmental Institutions

In the actual government of Nicaragua, there is no ministry or department for renewable energy. In general, energy conservation issues and renewable sources of energy have received very little attention from the government compared to -for instance- environmental issues.

At the International Workshop on the Rope Windpump (28 April 1998), the national Ministry of Agriculture (MIDINRA) showed its interest in the rope windpump technology by sending as a representative, Ing. Arkángel Abaunza. This indicates that there exists an awareness of the opportunities of this kind of technologies at some levels of the government, which might lead to a more active support in the future. Among other things, Ing. Abaunza stressed the importance that small farmers may have for the national economy if they start to irrigate their land by using the rope pump and become more productive.

8.2 International Donor Organisations

There is nation-wide support for the rope and washer handpump from international donor agencies. Most donor agencies active in Nicaragua have selected the rope handpump as the only type to be promoted. It is conceivable that they will also embrace other pumping systems such as the animal traction pump, the bicycle pump and the rope windpump, which are all extensions of the rope handpump. If this happens, the rope windpump will enjoy a very strong support for its large-scale dissemination in Nicaragua.

8.3 Agricultural Support Institutions in Nicaragua

The rope windpump has a potential in the sector of agriculture and cattle holders. The Instituto Nacional de Tecnología Agrícola (INTA), an important organisation active in this sector of interest for the dissemination of the rope windpump, until now has not shown much interest in windpumping. According to [27], INTA has promoted projects with hand rope pumps aiming at agricultural production.

8.4 Availability of Credit Schemes

Generally, an important barrier for the introduction of windpumps in developing countries is the high investment cost, which for a traditional windpump is three to five times higher than for a diesel or gasoline pump. Although a windpump is regarded profitable after 4 to 8 years (depending on the circumstances), this period is often too long for countries like Nicaragua, where it is difficult to obtain long-term loans.

Although the rope windpump has the advantage of a much lower investment cost (in the order of US\$ 750 - \$ 900), it is still too high for small farmers. Two credit schemes have been developed in the country, by CESADE and Bancosur, under which the rope windpump is an eligible technology.

8.4.1 CESADE

The non-governmental organisation CESADE allocates credits to rural farmers and co-operatives for investments in agricultural equipment. Since 1991 it provides loans to users to purchase a rope windpump, though only within rural development projects. About 29 of the 100 AMEC rope windpumps have been installed at farms of counterparts of CESADE with the aid of credits from CESADE's financial support fund FONCREP. This fund includes credits provided by the Dutch organisation NOVIB. The interest rate on the loans is 15% and payback periods can be 18, 24 or 36 months.

A guarantee must be given and can be land or cattle; it is also possible for other people to secure the loan (guarantors). In the case where a client does not pay back the loan, the organisation reserves the right to take back the windpump.

Up to April 98, not more than 22% of the total amount of loans given out for the AMEC rope windpumps, was recuperated. Of the 8 small farmers visited during the end-use survey, 4 had obtained the machine through a loan from CESADE. Only one of them had partly paid back his loan (62% of the total amount); the three others had as yet not paid back anything, although their windpumps dated already from '94, '95 and '97.

The head of CESADE's credit department, Mr. Leonardo Busto admits that recovering the loans is a problem, which makes it difficult for the fund to revolve effectively. In practice, the windpump has never been taken back, even if a client is able to pay back, but is not willing to do so. At the International Workshop in Managua, CESADE's director Dr. Allan Fajardo indicated that the organisation would improve the existing credit scheme.

8.4.2 OFICINAS DE BANCOSUR

In February 1998, *Oficinas de Bancosur* (previously named BANCAMPO) set up a credit scheme for financing of renewable energy equipment. It counts with a guarantee fund from the financing organisation E&Co LAC (based in the USA and Costa Rica). This scheme has become operational in February and according to the information of Luis Román in May 1998, had not given out any loan for rope windpumps at that time.

9. SOCIAL AND GENDER ASPECTS

9.1 *Impact on the Quality of Life*

In a number of cases of small farmers the windpump was showed to have some impact on their productive life:

- they started irrigating intensively a small plot of land
- they could keep several heads of cattle (cows, pigs, sheep etc.)
- they counted with an increased amount of water for domestic use

These achievements are a major step upwards in development and demonstrate the potential of the rope windpump to increase food production, provide more water, and sometimes generate more cash income.

9.2 *Impact on Health*

In previous studies carried out in Nicaragua, it is found that general health conditions for a family improve if the water use (per capita) is increased from about 10 litres/day to about 100 litres/day [11].

A rope windpump has sufficient pumping capacity to increase the available amount of water to a volume of 100 litres per person. As such, the rope windpump assists in helping to increase the health and hygiene conditions a family.

If a rope windpump is used, the well can never be sealed as well as in the case of a piston handpump. However, one can easily cover the well to give it sufficient protection against dirt and contamination. In the sites visited, this was not always done.

9.3 *Gender Aspects*

If applied for cattle watering alone, a windpump does not generally interfere with the occupations of women; this applies to both a traditional windpump and a rope windpump.

If a rope windpump is used for domestic water supply combined with a productive use (which is the case for the small farmers and the "special cases"), it has an impact on the situation of women. In a broader sense, as it is generally installed near the house, it affects the situation of all members of a family. In general, the windpump is received positively by all, independent of gender. The rope windpump is generally operated by men (the husband and older sons). Women and children are positive towards it in attitude, but rarely use it. They rely on the men for the water supply. If previously it was the woman's task to go for water, the rope windpump has shifted this towards the men. The women (and children) perceive this as an important alleviation of their daily occupations; the men are generally proud to take over this task, possibly since the operation of the machine also gives some status. Even compared to a handpump, the women may save considerable time per day, which they can now use for other tasks.

In the IRC report [1], the rope handpump was identified as primarily a woman's device. The rope windpump is certainly not, and a woman has to rely on other family members for water supply. Under certain conditions this means that if she runs out of water and her husband or sons are



working elsewhere or attending school, she has to wait until they return. The survey has not shown that this as a serious problem. In general, sufficient water storage is available for kitchen and patio use.

One of the reasons why women do not operate the machine is that they refuse to climb the tower. In the current design, the transmission rope of the windpump needs to be put in place occasionally. Improving the design may change this operational aspect and help to make the rope windpump user-friendlier for women.

Notwithstanding, more than one woman was found who actively take benefit from the rope windpump. Doña Mercedes, one of the women interviewed, states that she "would never go back to a bucket", since the windpump has made her life certainly easier. Another woman is Doña Viridiana (see photograph), who lives in the region of Leon and operates and maintains the rope windpump all by herself. She uses the windpump for irrigating a plot of about 1 manzana and obtained the system through a project in Chinandega, financed by the European Union. She grows vegetables and tells that she is very satisfied with the rope windpump.

10. THE ECONOMIC VALUE OF THE ROPE WINDPUMP

10.1 The Economic Value on a National Level

From a national point of view, the rope windpump manufacturing sector is very small and hardly contributes to the economy. Also, the number of people involved is negligible.

However, wind pumping potentially can have a substantial impact on the development of the rural areas as it provides one of the basic inputs: water. A better access to larger volumes of water can improve the quality of life, hygiene, and health conditions of many families, which will indirectly contribute to the national economy. The Ministry of Agriculture has mentioned the direct contribution to the economy resulting from an increased production by the group of small farmers, as another factor of interest.

The economy of the use of a rope windpump has a direct influence on the financial situation of an individual user. This topic is generally referred to as a financial analysis and will be dealt with in this chapter.

10.2 Financial Analysis for the End-Users

From the information about the operational experiences with the rope windpump as collected during the interviews with the various users, some general cases can be described and compared. Case I is a cattle farm where the options of a traditional windpump, the rope windpump and a diesel pump are compared. Case II is a small farm for which the potential benefits are calculated when using a rope windpump.

10.3 Case I: Cattle Owners

The economic benefits of a rope windpump are most readily expressed by carrying out a least-costs comparison between the rope windpump and alternative, competing pumping systems. In this section, the costs of the H-12-270 model are compared to those of the Chicago Aermotor and a diesel-electric pumping system. It is assumed that the three options are equivalent.

Table 10.1 shows the input data used. A water demand of 8 m³/day average is assumed as a typical figure, according to comments obtained from users and the experiences of the mission team. The cost of a new 3 meter Chicago Aermotor costs is in the order of US\$ 5,000,- to US\$ 6,000,-. The maintenance costs for this windpump are about US\$ 300,- per year, compared to US\$ 50,- per year for the rope windpump. The operator costs for the rope windpump are based on a wage of US\$ 2,- per day. The time involved is estimated at 2 hours daily and sometimes an operator controls more than one windpump. A diesel-electric system with a submersible, downwell pump as required for deeper wells, costs about US\$ 2,400,-. The investment cost for a 5 kW diesel engine driving a suction pump is established at US\$ 800,-, according [19]. It is assumed that the diesel pump needs about 1 hour per day operator time. The effective interest rate in the calculations is taken equal to 10%.

The configurations given here can be taken as an example of a pumping system based on each of the three technologies. Of course, other variations can be conceived for which the results will be somewhat different.

As seen before, the investment for the rope windpump can be up to six times lower than for a traditional windpump with a comparable water output. As indicated in Table 10., the costs per cubic meter (unit water cost) for the H-12 rope windpump are less than half those of the Aermotor and the diesel pump. This makes the rope and washer pump an attractive alternative for a cattle farmer.

LEAST-COST COMPARISON OF ALTERNATIVE WATER PUMPING TECHNOLOGIES FOR WATER CATTLE WATERING (NICARAGUA)			
	Chicago Aermotor	H-12 Rope Windpump	Diesel-Electric Pump
Application	cattle watering	cattle watering	cattle watering
number of head	200 cows	200 cows	200 cows
water requirement	8 m ³ /day	8 m ³ /day	8 m ³ /day
Nominal pumping capacity (pumping head 20m; wind speed 8 m/s)	1 l/s	1 l/s	2.5 l/s
cost	US\$ 5,000,-	US\$ 800,-	US\$ 2,400,-
lifetime system	20	12	6
water tank	US\$ 500,- (34 m ³)	US\$ 500,-(34 m ³)	US\$ 300,-(8 m ³)
lifetime water tank	30	30	30
installation, transport, civil works	US\$ 450,-	US\$ 110,-	US\$ 450
<i>Recurrent costs per year</i>			
maintenance costs	US\$ 300,-	US\$ 50,-	US\$ 150,-
fuel costs	none	none	US\$ 58,-
operator	none	US\$ 180,-	US\$ 90,-
Annualised life-cycle cost	0.0171 US\$/m ⁴	0.0073 US\$/m ⁴	0.015 US\$/m ⁴
Cost per m ³ (20 m head)	0.34 US\$/m ³	0.14 US\$/m ³	0.30 US\$/m ³

Table 10.1 Least-cost comparison of three competing pumping systems for cattle watering in Nicaragua: the classical Chicago Aermotor, the H-12 rope windpump, and a diesel-electric system with a submersible pump. The H-12 rope windpump has both the lowest investment costs and unit water costs.

10.4 Case II: Small Farmers

The economic use of the rope windpump by the group of small farmers is to generate a higher income from their agricultural activities. In some cases, a small farmer may evolve from the level of subsistence farming to small-scale commercial production. The extra water supplied by the windpump is one of the necessary inputs to enable a higher production.

The economic value of the rope windpump for irrigation by this group of users depends on an analysis of the costs of the windpump and the benefits obtained from the farm. This is a much more complex situation than for the cattle owner (in which benefits were disregarded) and requires much more information. In the case of the Nicaraguan rope windpump, most small farmers are "learning" both how to use the windpump and how to set up a good irrigation scheme. It was not possible to find something like a generalised "small farmer's business" that could serve for a cost-benefit analysis.

During the survey, eight small farmers were visited but only few of them had actually used the windpump to irrigate during the dry season, and over longer period (i.e. some years). The

information gathered was insufficient to obtain a complete picture of the economy of each of their farm.

Therefore in this section the case of a "hypothetical small farmer" is presented based on the data from the various users to estimate the income in the dry (from November to May) and the rainy season (from May to November), by using the rope windpump for irrigation. The analysis given may provide an idea about the potential benefits and extra yield of income for a small farmer who formerly produced only during the rainy season.

10.4.1 A hypothetical small farmer

A "hypothetical" small farmer has generally obtained his machine through some rural development or co-operation programme, as described in [19] and confirmed by the end-use survey. The pay-back conditions are very soft (and not always respected), but here we assume that the farmer has to pay back the loan (with interest) during the second, third and fourth year after acquiring the machine.

It is also assumed that the farmer has sufficient experience with irrigation in order to actually benefit from the windpump and that he has the required accessories (a storage tank, tubing, and valves) to apply the water in an effective way. In practice, one has seen that this is not common in Nicaragua and is only now being developed. Commitment for paying back the loans is not high and this does not stimulate the productive use of the windpump during the dry season. (In fact, the end-use survey has detected a number of end-users that had received the rope windpump almost "for free" and hardly appreciated it.)

For the "hypothetical farmer", it is assumed that a small H-8 windpump is bought together with a large storage tank (60 m³). The loan of US\$ 1,000,- is provided with an interest of 13.5 % on a yearly base; the pay-back period is 4 years and there is a one grace period of 1 year. The profile of the considered farmer is summarised in the Table 10.2:

CHARACTERISTICS OF A HYPOTHETICAL SMALL FARMER	
Land area	1 manzana
water requirements	max. 15 m ³ /day
windpump	H-8 rope windpump
storage tank	60 m ³
back-up	handpump
well capacity	15 m ³ /day
pumping head	20 m

Table 10.2 Characterisation of the "hypothetical" farmer. He has obtained a loan of US\$ 1,000,-, which he is assumed to pay back in four years.

From the end-use survey, the net income gained from the farm activities during the winter season are calculated at US\$ 916,- on the basis of a family in which two people contribute equally (2 x US\$458). (This corresponds to the cases of Donald and Pablo in the end-use survey [19]).

For the income during the summer season, one has assumed a production based on a mix of crops: herbs like "yerbabuena", frijol (beans), sandía (watermelon), tomate (tomato), pipián (pumpkin), pepino (cucumber), ayote and chiltoma. The income gained with this combination of products is approximately US\$ 1,670,- (and in practice will depend on the actual market conditions and possibilities). After subtracting the extra costs involved for the production (farm inputs: US\$ 385,-)

and transport (US\$ 180,-), one finds a net extra income from the windpump assisted summer agriculture, of US\$ 1,105,- (Table 10.3).

Alternatively, a farmer can work during summer as a labourer in the coffee or sugar cane harvest on the large agricultural estates or work in the city. This is generally the case in the country; the earnings involved with these activities add up to about US\$ 600,-.

COST-BENEFIT COMPARISON FOR A SMALL FARMER		
<i>Income source</i>	<i>without windpump</i>	<i>with windpump H-8</i>
Rainfed agriculture (winter)	US\$ 916,-	US\$ 916,-
Irrigated agriculture (summer)		US\$ 1,670,-
- Farm inputs and costs		-US\$ 385,-
- Transportation to market		-US\$ 150,-
<i>Net result</i>		US\$ 1,105,-
Off-farm work (summer)	US\$ 600,-	
<i>Total income</i>	US\$ 1,516,-	US\$ 2,021,-
- Payback loan (2 nd , 3 rd , 4 th year)		-US\$ 335,-
<i>Net income (2nd, 3rd, 4th year)</i>	US\$ 1,516,-	US\$ 1,686,-
<i>Net income (after 4th year)</i>	US\$ 1,516,-	US\$ 2,021,-

Table 10.3 Cost-benefit comparison of a rope windpump acquired by a hypothetical small farmer. The income with a windpump is about 30% high than without under the stated conditions.

In this hypothetical case, it is seen that the use of a rope windpump is just economically beneficial. It is clear that the results depend on the assumptions for the considered farmer. Collecting data about actual costs and benefits from a selected group of users that are obtaining promising results may allow for a more detailed analysis in the near future. A few cases have been identified during the end-use survey, which could be monitored, by a limited end-use survey once a year.

10.5 The "Special Cases"

The owner heavily "subsidises" his agricultural/cattle activities by channelling his income obtained from other economic activities towards the farm business. This complicates a cost-benefit calculation of the farm business alone; besides, the activities among this group are diverse. As this evaluation focuses on the potential of the rope windpump for the small farmers, no financial analysis for this group has been carried out.

Note: it is remarkable that the small farmers and the "special cases" are in a process of learning how to use the windpump, at the same time as they try to set up a practicable irrigation scheme. Both are new for them and require new skills; it will take them some years before they will reach an optimal use.

Experiences with the introduction of windpumps for irrigation elsewhere in the world do not recommend the combination of both the aspects of new technology with new farming practice. This implies too many uncertainties. However, in Nicaragua the situation is probably less critical, partly because of the low initial investment required.

11. TRANSFER TO FOUR COUNTRIES

11.1 Introduction

As part of the project, a first transfer of the rope windpump to countries in Latin America was undertaken, scheduled as "project phase III". Main objective of this activity was, to initiate the



Participants of the International Workshop visiting the demonstration site at the premises of AMEC. dissemination of the rope windpump technology and making maximum use of the impetus gained during the National and International Workshops in April 1998.

A first selection of the counterparts in the target countries was made during the International Workshop in Managua (project phase II). Subsequently, more information was obtained by means of a detailed questionnaire. Using both sources of information, four countries were selected, which showed the most promising characteristics for transfer of the rope windpump and with a serious local counterpart.

For each target country a package was prepared containing the drawings, manuals and some parts pre-manufactured by AMEC in Managua: adapters and connectors for tubing; wooden bushings for pump and rotor shaft; rope pumps components (pistons, rope, guides). Also, a number of jigs were prepared to facilitate the local production of the main assembly and the rotor [29].

The following documents were used for the transfers:

- methodology and motivation of the transfer
- a questionnaire
- a written agreement about the realisation of the transfer
- drawings
- manuals for siting, installation and maintenance

According to the original calendar this phase was to be concluded by the end of 1998, however, the appearance of hurricane "Mitch" forced all parties to redefine their activities and priorities. Therefore, the Royal Embassy of the Netherlands in Managua conceded a prolongation of the project until 30 May 1999.

The following sections give a brief description of the transfer of the rope windpump to four Latin America countries: Peru, Bolivia, Guatemala and Cuba.

11.2 Peru

The transfer to Peru was carried out by Henk Holtslag and Luis Román from 7 - 17 September 1998. The manufacturer chosen was Workshop Ricardo Zimic in Lima, with a reasonable track record in windpump manufacturing. The owner, Mr. Zimic was one of the participants of the International Workshop on the Rope Windpump in Managua and was supported by Mr. Teodoro Sánchez from ITDG's local office in Lima.

Mr. Zimic has a small workshop in Lima, whose main activity (70%) is the production, installation and maintenance of mechanical windpumps; he also repairs other types of water pumps and carries out other kinds of small metal works. Basic machinery for welding, cutting and drilling is available, while more complex handling that requires a mill or a lathe is subcontracted. Mr. Zimic is about 60 years old and employs one to three technicians depending on the volume of work. As he will eventually retire, an Italian colleague (living in Lima) may possibly take over the workshop.

Over the last 20 years Zimic has produced about 150 windpumps of 4 different types, varying from a simplified American multiblade to a copy of the Dutch 12PU500; of the latter about five units were installed. The machines cost between US\$ 3,000.- and US\$ 4,000.-, for a 3-m rotor diameter and a 6-m high tower (this includes installation costs). Thanks to the centralised location of the workshop, the windpumps draw a lot of attention from the people passing by. Daily two to five people visit the workshops, most of them farmers who look for a suitable pumping solution.

To meet the variable wind conditions, ITDG and Zimic had applied for a "multigiratorio" model, as this was considered most generally applicable in the central region of Peru. The windpump equipped with a 1" rope pump was installed on top of a 6.4-m tower, and pumps water from a plastic demonstration tank. Some components required adaptation to cope with local circumstances (see Table 11.1).

The sales price of the rope windpump is estimated at approx. US\$ 1,500,- (including the installation), which is about 90% higher than in Nicaragua.

Results and follow-up

Zimic's intention is to show the windpump to interested farmers and development organisations and is pondering about installing the demonstration model at a real site near to Lima. In order to mitigate the investment for setting up an own production of the rope windpump in the future, he expresses the need to collaborate with local organisations, first of all ITDG. On the other hand, ITDG has no direct funds available for the implementation of the windpump, but states that it will do so as soon as there will be a real demand for it. Other organisations that have shown interest in the rope windpump are *SNV*, active in the Cajamarca area in Northern Peru, and the *Grupo de Apoyo al Sector Rural*, representing the *Pontificia Universidad Católica del Perú* in Lima.

Opportunities

A possible application for the rope windpump in Coastal Peru would be to substitute the artisanal Miramar in the north of the country (Piura and Lambayeque). Here the wind direction is fairly constant -from the Pacific-and the wind power is used to lift water from the Chira river over a head of a few meters.

Ricardo Zimic states that the demand for windpumps in and near Lima has fallen over the last years, mainly because of the high investment cost. Windpumps have also acquired a rather negative reputation in the central coastal region near Lima, particularly due to the introduction of inappropriate designs and bad maintenance. However, there is still an important demand for cheap water supply systems; there are quite some people who believe that windpumps have an important role to play "once the right windpump is there".

Zimic claims that there is a demand "even bigger than for windpumps" for a low-cost wind battery charger, especially in areas with wind speeds of 3 m/s and better. He therefore showed much interest in *CESADE's* small windcharger.

11.3 Bolivia

The transfer to Bolivia took place directly after the one to Peru, from 17 – 26 September 1998. The workshop chosen belongs to the *Department Renewable Energy & Hydraulic Technology* of the *University of Bolivia* in La Paz. The head of the Department, Mr. Andrés Calizaya was one of the attendants of the Workshop in Managua and claimed the relevance of the rope windpump technology for Bolivia. The Department's primary field of interest is hydro energy but have now made a beginning with wind electricity generation, to be followed by wind water pumping. The University is involved in rural electrification and the execution of hydroelectric pilot projects. Some of the activities receive funding through Embassy projects from Switzerland and the Netherlands.

The workshop employs three to six technicians and is equipped with drilling and welding machines, and also a lathe. It produces prototypes of small and medium-size hydro-turbines. Mr. Calizaya is also the direct responsible for the workshop.

About five years ago, the workshop constructed a number of prototypes of a locally designed windpump based on the "American multiblade". Instead of a gearbox, a direct-drive transmission was used. The windpumps were installed in the south of the country but the experiences were rather negative, basically because of technical and maintenance problems. None of the units is still operational, and the production has stopped for three years ago.

The main goal of the university to apply for the Nicaraguan rope windpump technology is, to acquire up-to-date knowledge on windpumping and to count with a well-performing system after their unsuccessful first attempt. The university would demonstrate the rope windpump to other interested organisations, institutions and manufacturers. A direct link to the local manufacturer of hydro-

turbines HIDROMECA exists in the person of Mr. Calizaya, who is the general manager. This private factory would be interested in producing the rope windpump on a commercial basis.

According to the data provided by Mr. Calizaya, the demonstration rope windpump installed was the "multigiratorio" version, coupled to a 1" pump and with 6-m tower. The unit was placed on a cement demonstration well at the University of Bolivia. Some modifications were put through to deal with locally available materials. The sales price of the whole rope windpump is estimated at about US\$ 1,200,- including the installation, slightly above the price in Nicaragua.

Results and follow-up

The University has expressed the intention to demonstrate the rope windpump to interested organisations. In order to gain more practical experience with the system, it is planned to relocate it in the field and possibly, install a second windpump in the north of the country. Since own funding is insufficient, the institute has to rely on assistance from local rural development organisations. Another possibility identified and mentioned by the University would be integration into an SNV development project. Mr. Calizaya also claims a good potential for the rope windpump with animal traction and would be interested in its transfer to Bolivia as well.

Opportunities

During the transfer in Bolivia, contact was sought with the local SNV office as well as a representative of Dutch consultant ETC. Both claim an interesting potential in the district of Santa Cruz, traditionally a windpumping area. SNV's local field director confirmed the interest from his organisation in the rope windpump technology, which might be included in their irrigation projects in the future. However, there should first be some convincing results with the system in Bolivia.

Also, local windpump manufacturer SEMTA has shown interest in the rope windpump.

11.4 Guatemala

The transfer mission to Guatemala directly suffered the consequences from hurricane "Mitch" that impacted on the coast of Central America mid October 1998. The first mission, starting on 13 October, had to be cancelled on the second day and for several months, the priorities in the region would be others than the rope windpump. Finally, a new mission was prepared and executed from 9 – 19 February 1999 by Luis Román (AMEC) and Henk Holtslag and Enock Matute from CESADE.

The local recipient chosen was Workshop Galdamez, located on the Pan-American Highway in the Zacapa region in the northeastern part of Guatemala. It is a small workshop mainly dedicated to the production and repair of agricultural machinery, such as tractors, harvesting machines and water pumps. The workshop is equipped with machines for cutting, welding and drilling; it also has a number of lathes. It has limited space for the construction of large elements, such as a windpump tower. The owner is Mr. Galdamez who employs three to seven people depending on the amount of work.

Galdamez was brought into contact with the rope windpump technology through the mediation of Mr. Hugo Arriaza from NRECA-Guatemala. NRECA collaborates with the non-governmental organisation CARITAS in the Zacapa region and motivated two members to join the International Workshop in Managua. Both, Mr. Carlos Sett from CARITAS-Guatemala and Mrs. Rosina Estrada from the office in El Salvador, became convinced about the potential of the rope windpump in Central America. An analysis of the local situation led them to choose Guatemala for a first transfer.

During the transfers to South America, one had noticed that people who are not familiar with the concept of the rope pump do not immediately grasp the idea. Therefore, it was decided to first build a simple rope handpump and explain it extensively. This pump was installed on an existing domestic well near the workshop and will serve as a demonstration rope handpump for household purposes. While previously the well was equipped with a bucket and a rope, one can now easily observe the improvements: a much smoother and easier pumping action, a better covering of the well, and cleaner water.

Afterwards, the rope windpump was built and installed on a nearby well. As the wind regime in Zacapa is similar to that in Nicaragua, a standard (H-270) model was chosen for transfer, equipped with a 3/4" pump and a 6-m tower. The well depth is 14 m. Close to the well there is a water tank with a volume of 12 m³ used for drip irrigation of fruit trees. On this field site, the windpump has been devised as a backup for the six months long, dry season when rain and surface water run out of supply. During the transfer, both people from Workshop Galdamez and from CARITAS assisted.

Also in Guatemala it was necessary to make some adaptations to several components. The cost of the windpump has not been determined but will be comparable to Nicaragua.

Results and follow-up

Galdamez and CARITAS will demonstrate the rope handpump and windpump to interested farmers, other people and development institutions. The workshop is prepared to expand its capacity in case a real demand for the windpump will develop. Galdamez also foresees a market for other rope pump technologies, in the first case the bicycle pump "Bicibomba" and the electrical rope pump.

NRECA currently does not have funds available for implementation of the technology but would seek for funding as soon as there the rope pump is proving its potential in Guatemala. CARITAS will support the workshop in the near future by demonstrating the installed units to the public and providing information.

Opportunities

CARITAS reports that in the first two months after the transfer, many people visited the site. Informed about the expected sales price, about 10 families took an "option" on the rope handpump and 5 farmers showed interest in purchasing the windpump. NRECA states that also in other areas in the country there is a potential for the rope windpump. The organisation is working out concrete proposals for further dissemination of the rope pump technology in Guatemala, including the bike pump and other traction methods. It also claims an important market for CESADE's small windcharger and proposes the installation of a number of units verify the feasibility under local conditions. The organisation has established direct working relations with CESADE and AMEC to effectively benefit of the existing experiences in Nicaragua.

11.5 Cuba

The fourth transfer –to Cuba- took place a few days after the mission to Guatemala, from 24 February till 6 March. The local counterpart was the IIMA (Agricultural Mechanisation Research Institute) at Boyeros, near La Havana. The institute has a large workshop employing about 30 people and is well equipped with lathes, milling machines and drilling and welding tools. Its primary activity is the construction of prototypes of new machinery and the production in small series of agricultural machinery, such as harvesting machines, ploughs, sowing machines for animal traction, and so on. The whole workshop covers an area of about 1,000 m².

The IIMA was represented at the International Workshop on the Rope Windpump in Managua by one of its engineers, Mr. Braulio Campos. Regarding the important potential the rope windpump may have in Cuba, the institute applied for a transfer.

Based on the available wind data the model chosen for transfer is the standard H-270 model, equipped with a 1" pump and a 6-m tower. Also a rope handpump was built. The chosen site is the factory at the Carretera Fontanar. During the production several of the technicians were present, as well as the director. It was found necessary to make a large number of adaptations in the choice of materials, either because the materials used in Cuba do not correspond with the standards in Nicaragua, or because it was too difficult to obtain them quickly. Angle irons for example, were produced by welding together strips of steel sheet. The changes are listed in Table 11.1.

The institute could not determine the estimated cost price of the rope windpump, since not all the required information was available. Yet, it is expected that the sales price will be lower than in Nicaragua because of the low production costs and relatively high efficiency.

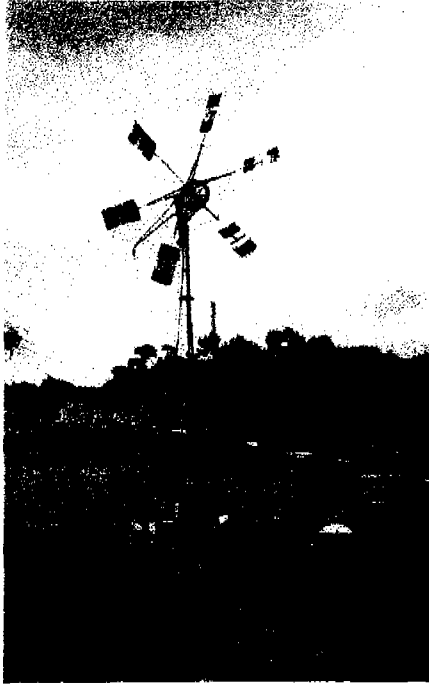
Results and follow-up

IIMA will demonstrate the rope windpump to other institutes active in agricultural development and install a second rope windpump at a cattle farm near La Havana. The director of the institute, Mr. Bouza, pointed out that the IIMA would do some basic tests with the rope windpump and possibly install more units in the future. To this purpose, it may benefit from the regular state support and/or receive additional funding from foreign organisations. If the indications are positive, the institute will set up a further implementation programme that includes training on the production; the installation of more demonstration windpumps combined with distribution systems; contacts with rural development institutions, etc. The institute has asked CESADE to co-operate also in the future.

Opportunities

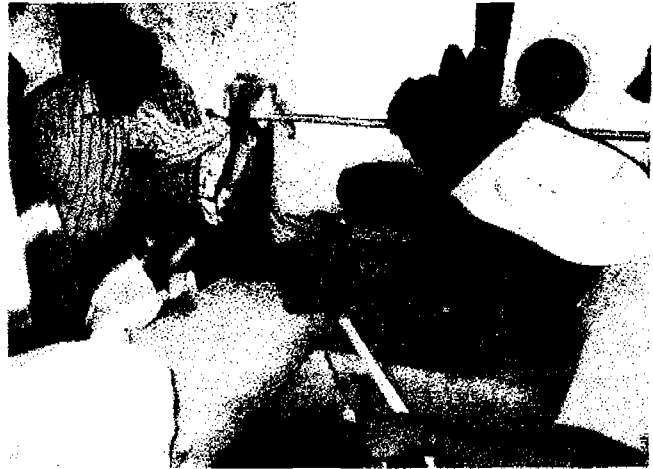
IIMA expects a potential in regions such as Camaguey and the eastern part of the island. At household level, it foresees also a potential for the rope handpump. The implementation of the windpump would mainly occur through state institutes and may be subsidised to a more or lesser degree. While under the Cuban system more than 7,000 windpumps have been sold to farmers, the criterion for feasibility for the rope windpump would be its cost-effectiveness.

The combination of an electric generator and a windpump would be a novelty in Cuba and find application in areas without access to the grid. The small windcharger may be especially interesting in Cuba, since fuel is relatively expensive and one may expect little competence from photovoltaic solar panels.



The *multigratorio* wind rope pump installed near the University Bogota in Bolivia

Demonstration of rope pump technology to technicians of Caritas Guatemala



Director of IIMA (center) Cuba inspecting the functioning of the rope wind pump



Louis Roman (r) explaining the construction of the bushing to Mr. Zimic (l) Peru



11.6 Production, Economy & Application in Latin America

During the transfer to the four selected manufacturers, it has become clear that local production inevitably will lead to modifications in the design and the choice of standard materials. In South America, the standard 1" PVC tubing was slightly smaller than in Central America, which made it necessary to adapt the plastic pistons for the rope pump pre-manufactured in Nicaragua. In Cuba, most iron material is different from Nicaragua and sometimes difficult to obtain. The most significant change concerned a general reinforcement of the rotor blade mounting, by putting the blade supports at a distance of 280 mm instead of the 250 mm used in Nicaragua. In none of the cases however, the modifications caused a delay in the production of the rope windpump, which was always completed in time. Apparently the current rope windpump design is not too critical and it is not expected that these small changes will affect the functioning or reliability of the demonstration units. A listing of the changes in each of the four countries is given in the Table 11.1.

MODIFICATION OF COMPONENTS DURING TRANSFER				
	Peru	Bolivia	Guatemala	Cuba
<i>Proposed model</i>				
	H-360 "multigiratorio"	H-360 "multigiratorio"	H-270 windpump	H-270 windpump
	1" pump	1" pump	3/4" pump	1" pump
	6-m tower	6-m tower	6-m tower	6-m tower
	plastic demonstration tank	cement demonstration well	14-m well	demonstration well
<i>Modifications</i>				
- tower	6.4 m	--	--	--
- tail vane	thinner, corrugated steel with extra weight	thinner, corrugated steel with extra weight	thinner, corrugated steel with extra weight	0.55 sheet instead of corrugated steel #26
- pistons *)	1 mm less diameter than in Nicaragua	1 mm less diameter than in Nicaragua	1 mm less diameter than in Nicaragua	--
- pump **)	--	--	--	14" pump pulley instead of standard 16"
- rotor	blade support distance of 280 mm instead of 250 mm	blade support distance of 280 mm instead of 250 mm	blade support distance of 280 mm instead of 250 mm	blade support distance of 280 mm instead of 250 mm
	--	--	thinner blades of #26 instead of #24; reinforced by extra rim	--
- materials	--	--	--	3 mm sheet instead of 18" angle iron
	--	--	--	4 mm sheet instead of 3/16" angle iron
	--	--	--	tube wall thickness 3.1 mm instead of thickness 2.5 mm
	--	--	--	bolts M10 instead of bolts and threads 3/8"
*) to adapt to local PVC tubing				
***) to adjust to well depth				

Table 11.1 Modifications in the original design and components of the rope windpump put through during the transfer

The main purpose of these first four transfers was to produce and install a rope windpump in several countries outside Nicaragua and give sufficient information for its promotion and demonstration. It was not expected that after this transfer, the local recipients would already be able to set up a production of the system independently. With an exception perhaps of Cuba, additional training will certainly be needed on production skills in most countries.

During the missions to South America, one became aware of the convenience to first explain and demonstrate the working principle of the rope pump itself, before embarking on the construction of the windpump. One could expect a more participative attitude from the workshop people, if they would have a better understanding of the functioning and construction of the system. Therefore, in Guatemala and Cuba first a rope handpump was built.

The economy of the rope windpump in countries others than Nicaragua can vary significantly. Materials may be more expensive, or cheaper; labour costs vary from one place to another; as well as the costs of production and machinery. Ricardo Zimic in Lima includes transportation and installation in a total cost, and assists in the preparation of the well. AMEC uses a fixed tariff per kilometre, while well drilling would be an additional job. Finally, tax rates and the availability to adequate credit schemes determine the cost of capital. All these elements will be reflected in the actual value of the overall investment needed for the windpump.

The conditions for competitive pumping technologies also vary from country to country. In some countries, diesel fuel may be cheaper than in others. Supply may be irregular, or perhaps very good. Spare parts may be difficult to obtain, or maintenance infrastructures may be insufficient. The local situation influences the initial and recurrent costs of each pumping option but also its reliability. In the case of the windpump, one should never forget to examine the available wind resource and how it is related to the demand for water. The system efficiency and availability, pumping height, initial and recurrent costs and the availability of wind, determine the unit water cost (US\$/m³). Whether this last figure is feasible or not to justify a certain application –in the sense of economy- depends on the importance of the water (drinking water), the added-value of an economic activity (cattle farming) and the presence of cheaper competing production methods (irrigation).

From the information gathered during the transfer one found significant differences in prices of competing pumping technologies. Also, several counterparts indicate a real sales price for the rope windpump of about US\$ 1,200,-. This will change the economic picture drawn in section 10.3. As an example, NRECA has reported a sales price for a 3-m “American” windpump in Guatemala of only US\$ 2,500,-. This figure, which would concern a traditional windpump design imported from Mexico of Brazil, is half of the cost of a Chicago Aermotor in Nicaragua (but has not been verified). Comparing the economy of the relatively expensive rope windpump (US\$ 1,200,-) for cattle farming with this cheap traditional windpump, one may find a result as given in Table 11.2 that will probably be close to a “worst case” for the rope windpump. Still, the rope windpump seems an attractive option with very reasonable unit water costs.

One of the objectives of the International Workshop in Managua and the subsequent transfers of the rope windpump was, to detect possible applications outside Nicaragua. In view of the responses obtained, one must conclude that people first need to “process” the new technology before they start thinking about new applications. However, an interesting application, for instance in Peru, may be low-head pumping. Here, the rope windpump could replace the artisanal Miramar and would compete with the relatively cheap diesel-suction pump. As an example, Table 11.3 gives a first estimate of the economy of the rope windpump for this application.

EXAMPLE OF ECONOMY OF ALTERNATIVE PUMPING TECHNOLOGIES FOR CATTLE WATERING IN LATIN AMERICA			
	"American" windpump (regional production)	H-12 Rope Windpump	Diesel-electric Pump
number of head	200 cows	200 cows	200 cows
water requirement	8 m ³ /day	8 m ³ /day	8 m ³ /day
assumed head	20 m	20 m	20 m
cost	US\$ 2,500,-	US\$ 1,200,-	US\$ 2,400,-
water tank	US\$ 500,- (34 m ³)	US\$ 500,- (34 m ³)	US\$ 300,- (8 m ³)
installation, transport, civil works	US\$ 450,-	US\$ 110,-	US\$ 450,-
maintenance costs	US\$ 300,-	US\$ 50,-	US\$ 150,-
fuel costs	none	none	US\$ 60,-
operator	none	US\$ 180,-	US\$ 90,-
Annualised life-cycle cost	0.012 US\$/m ⁴	0.008 US\$/m ⁴	0.015 US\$/m ⁴
Cost per m ³ (20 m head)	0.24 US\$/m ³	0.15 US\$/m ³	0.30 US\$/m ³

Table 11.2 Comparison of unit water costs for alternative pumping technologies for cattle watering, putting an expensive rope windpump, a cheap "American" windmill, and a diesel-electric pump. Under these conditions, the rope windpump is 35% cheaper than the classical windpump and 50% cheaper than the diesel option. The unit water costs are comparable to those found in Table 10.1.

EXAMPLE OF ECONOMY OF ALTERNATIVE PUMPING TECHNOLOGIES FOR LOW-HEAD PUMPING IN LATIN AMERICA			
	"American" windpump	H-12 Rope Windpump	Diesel-suction Pump
water requirement	30 m ³ /day	30 m ³ /day	30 m ³ /day
assumed head	6 m	6 m	6 m
cost	US\$ 2,500,-	US\$ 1,200,-	US\$ 800,-
water tank	US\$ 500,- (34 m ³)	US\$ 500,- (34 m ³)	
installation, transport, civil works	US\$ 450,-	US\$ 110,-	US\$ 50,-
maintenance costs	US\$ 300,-	US\$ 50,-	US\$ 100,-
fuel costs	none	none	US\$ 60,-
operator	none	US\$ 90,-	US\$ 45,-
Annualised life-cycle cost	0.011 US\$/m ⁴	0.006 US\$/m ⁴	0.006 US\$/m ⁴
Cost per m ³ (6 m head)	0.07 US\$/m ³	0.04 US\$/m ³	0.04 US\$/m ³

Table 11.3 Comparison of unit water costs for low-head pumping for the H-12 rope windpump, a cheap "American" windmill, and a diesel-suction pump. For low-head applications (max. 7 m) the diesel-suction pump and the rope windpump have similar unit water costs; the classical windpump is about two times more expensive.

12. CONCLUSIONS

12.1 General Conclusions

The unique concept of the Nicaraguan rope windpump produced by AMEC avoids a number of typical problems encountered in classical mechanical windpumps. As a result, a lightweight, straightforward construction is obtained with a remarkably high water output. While it is technically reliable (under Nicaraguan conditions), the needed initial investment has dropped significantly compared to a classical "American" windpump. Costing about US\$ 800,- in Nicaragua, the difference with a classical windpump may be as high as a factor 6. With this achievement, the rope windpump not only establishes itself as an economically attractive choice for cattle farmers. It also opens the perspective of profitable small-scale irrigation methods for the sector of small farmers in Nicaragua and abroad, for whom the high initial investment of other pumping technologies is usually prohibitive.

The recurrent costs of the rope windpump are modest and ensure a unit water cost low enough to make the rope windpump an attractive alternative to existing pumping technologies available in the country. A first analysis of the economy of the rope windpump based on the limited field data recollected during this project yields an estimate of US\$ 0.14,- per m³ pumped water at a pumping head of 20 m. This is less than half of the unit water cost for a classical windpump used in Nicaragua for cattle watering (the Chicago Aermotor). If the rope windpump is used for irrigation by small farmers, an analysis of the costs and benefits reveals an income increase of about 30%. This result is based on limited field data and assumes access to appropriate credit schemes.

The workshop Aerobombas de Mecate (AMEC) is a small but sound business with a record of eight years of development and production of the rope windpump. It has certainly shown that a small manufacturer without advanced equipment can produce the device with an acceptable quality and can make a profitable business out of it. For the development of the product, it has received some external technical assistance from the local non-governmental organisation CESADE, who has also offered credit facilities to open the market.

The evaluation mission confirms the statement of the designers, that the rope windpump can be maintained and kept in operation by the users themselves. This is due to two main reasons: 1) no heavy equipment is needed for lifting and maintaining the rope pump, while spare parts (rope and washers) are readily available -because of the existing, widespread support infrastructure for the rope (hand) pump which has grown during the last decade; 2) small damages to the windmill structure are often repaired by the user himself with some creativity and locally present scrap material.

An inventory of the current status of about 35 of all (approx. 100) rope windpumps installed by AMEC, shows that about three-quarter is operational and in use. Technically, more than four-fifth of all machines is functioning. Considering only the latest versions, one may conclude that the standard model is technically reliable under the specific conditions of Nicaragua.

The current standard model of AMEC's rope windpump has one design limitation. As the transmission rope does not pass through the centre of the tower but outside of it, the windmill head cannot turn freely to direct itself into the wind. If the head turns too far from the neutral position, the transmission rope falls off and the user has to climb the tower and replace the rope. This design limitation is not much of a problem in areas with a constant wind direction but reduces the functionality of the system under variable wind conditions. Then the rope windpump requires a lot of attention to keep it operating, which is inconvenient and makes the product less acceptable for the

more demanding customer. AMEC's *multigiratorio* model has a modified transmission to eliminate this drawback, but is still under development.

Currently, the market for the rope windpump in Nicaragua consists mainly of two sectors, i.e. the relatively large cattle farmers, and the small farmers. The first sector represents a commercial market that considers the rope windpump as a possible, attractive alternative to competing pumping methods. The cattle holders generally purchase the rope windpump out-of-the-pocket.

The introduction of the rope windpump among the small farmers as yet has been stimulated with the aid of credit schemes, for example from CESADE. One has recognised the need to improve the current credit facilities and guarantee a productive use of the windpump. The growing initiatives to address this point, the increasing demand both from cattle holders and small farmers, and the increased interest from implementing organisations are positive indications for the development of a commercial market in the sector of small farmers.

The rope windpump has the potential to bring along important improvements in quality of life, especially for the sector of the small subsistence farmers and their families. The majority of the users, both men and women, are quite satisfied with the rope windpump and perceive it as a step forward in development. Although the current product will not always be satisfactory for all users, there certainly seems to be a market for the rope windpump in Nicaragua.

During the scheduled transfer activities to four Latin American countries, the rope windpump has been produced and installed in co-operation with local manufacturers. Several modifications at component level were necessary to cope with varying local standards and material sizes. In none of the cases this caused a significant delay in production time. Apparently, the rope windpump design is not too critical and can be adapted quickly to local conditions. This is an important asset for dissemination and sustainability.

In general terms, both the rope pump itself as the windpump have drawn the attention from people interested in water supply in the receiving countries. The local parties have little resources available to actively promote and implement the rope pump at a larger scale; they first want to demonstrate the rope (wind)pump to the public and see if a real demand will develop. In Guatemala and Cuba, the local counterparts are working on a follow-up for promotion and production of more units and apparently, the local support infrastructure is quite good. In order to benefit from the experiences in Nicaragua, they have asked CESADE to stay in contact and work together. In Bolivia and Peru, the manufacturers may need additional help in order to reach a larger public, since the local development organisations will only embrace the technology once it has proven its usefulness under the prevailing conditions in these countries.

With the perspective of a growing market for the rope windpump in Nicaragua, particularly among a certain category of end-users, one may also expect a market in other countries and under similar conditions. The transfer experiences in Cuba and Guatemala certainly confirm this statement and if effectively supported, the rope windpump technology may spread faster here than in Nicaragua. In Peru and Bolivia the general attitude towards windpumping is not very favourable due to bad experiences in the past; this is an extra barrier that asks for an active promotion and demonstration approach. At this stage, it is unknown if the transferred "multigiratorio" model will perform satisfactorily under the expected variable wind conditions in South America. However, in both countries one has identified areas with wind conditions and end-users where the standard model may perform well.

It is certainly worthwhile to further support the dissemination of the rope handpump and rope windpump technology to countries outside Nicaragua. Actually, it is the concept of the rope pump and the technical realisation of its combination with a range of different traction methods, which should be promoted. It is basically its flexibility which makes it likely that one of the combinations

will match with a local need for water, among one or more groups of users. The rope windpump is an important option that uses the rope pump concept and may be applied for pumping significant volumes of water. While the application of AMEC's standard rope windpump may be restricted to areas with specific wind conditions, a more universal design would certainly have large opportunities for dissemination in Latin America. By involving more people in the development of the rope pump technology and its different traction methods, one may expect that the current systems will mature more quickly, and obtain adequate solutions for different working conditions.

12.2 Conclusions on Specific Aspects

12.2.1 Technology, Local Production and Maintenance

The rope windpump technology is better adapted to the local situation than a traditional windpump, regarding the following aspects that set the context in Nicaragua:

- it addresses market sectors that are not served by a classical windpump
- the technology is straightforward and easily understood by the user
- the relatively low initial investment is affordable for a much larger group of users
- the construction is based on locally available materials
- it benefits from existing maintenance infrastructures, especially for the rope pump
- is produced entirely in Nicaragua, without a need for imported components

The overall objectives set forth by the designers have certainly been achieved:

- the low initial investment of US\$ 700,- to US\$ 800,- (upto 6 times below that for a traditional windpump in Nicaragua) brings wind-assisted irrigation within reach of the group of small farmers
- the costs of operation and maintenance are sufficiently low to ensure an acceptable unit cost of water (US\$ 0.14 at 20 m head)
- the overall weight of the rope windpump of about 163 kg (about 4 times lower than for a traditional windpump) allows a fast, easy and less costly transport and installation
- most maintenance on the windmill is carried out by the user without the need for expensive tools
- maintenance and repair of the rope pump is easily and quickly done by the user, which is an important asset compared to the traditional windpump equipped with a piston pump
- the rope windpump can be produced in a local workshop, since the construction does not involve complex manufacturing skills or heavy machinery; and it is built from locally available materials

AMEC's current standard model (the H-270) is specifically designed for areas with a more or less constant wind direction (which is the case in many regions of Nicaragua). Under variable wind conditions, the rope windmill needs frequent attention during operation to check the functioning of the transmission rope and reposition it if necessary. This reduces the functionality of the system.

AMEC's H-360 model or *multigratorio* is a first step towards a more universal rope windpump; this type is still under development.

12.2.2 Field Operation, Technical Reliability & Performance

An examination in the field of about one-third of all installed AMEC windpumps (35 of all 100 units) shows that:

- three-quarter of the machines is effectively used
- technically, four-fifth of all the machines is operational

Since the evaluation¹ included some of the oldest models of 6-7 years ago, one may conclude that the present standard rope windpump is technically reliable under the specific conditions of Nicaragua.

The measurements of the system efficiency and pumping capacity show indicate:

- an overall system efficiency of about 8%
- a design output of 1 l/s and a maximum output of almost 2 l/s (using a 1" pump size)
- a volumetric efficiency of the rope pump of max. 85%

These values are acceptable and correspond to the expectations of the design.

With respect to long-term output and availability, no reliable data could be obtained during the measurement period.

12.2.3 The Rope Windpump for Electricity Generation

The combined system of a rope windpump with an imported permanent-magnet generator (150W):

- is a conceptually very interesting system to satisfy to basic needs in the rural area
- is technically and operationally more complex than a single water or electricity producing windmill
- is more costly than each of the separate systems alone

At present, the two units designed and installed by AMEC are technically not mature.

The AMEC windcharger (60 W) based on the rope windpump technology is very promising and seems technically reliable and cost-effective.

¹ To determine the score for "effectively used windpumps", one has considered the machines rejected by the owner (due to attitude or dissatisfaction) and those machines exhibiting some technical failures (32 in total, of which 23 were operational). The figure for "technically operational" units does not consider rejected windpumps and covers a total of 28. The figures include older versions that were less reliable. A survey of the recent models only would show a better score than indicated here. As only few data are available, no figures are specified for separate versions or models.

12.2.4 Market Profile for Rope Windpump in Nicaragua

The market characteristics as found for the different users of the rope windpump may be derived from Table 12.1. In general, one has observed a growing demand for the rope windpump in the country.

	<i>Cattle farmers</i>	<i>Small farmers</i>	<i>"Special cases"</i>
financing	own resources	rely on credits	own resources
motivation for purchase	least cost option for cattle watering	additional income yield new agricultural techniques & products	new agricultural techniques
market requirements	promotion appropriate design	credit facilities integration into agricultural projects	promotion

Table 12.1 Main characteristics of the different market segments for the rope windpump in Nicaragua.

12.2.5 AMEC's Manufacturing and Business Perspectives

The local workshop AMEC that produces the rope windpump:

- has proven capable of producing the rope windpump in its small workshop with a reasonable quality level using simple equipment only; compared to a good engineering workshop with skilled personnel, its quality level could be improved
- has developed into a sound commercial business (albeit a small one)
- has actively sought publicity and invested about 5 to 7% of the total turnover to promote the rope windpump

With regard to after-sales service and promotion in the remote areas, there is a need for improvement.

12.2.6 Gender & Acceptance

The rope windpump alleviates the task of women and children to collect water for the household. Time is saved, which can now be used for other tasks.

The operation of the rope windpump is done by men. The rope windpump is typically a "man's device", unlike the rope handpump.

The majority of the users are found to be satisfied with the rope windpump. The more demanding user sometimes feels less comfortable because of the required daily attention and design limitations.

12.2.7 Impact on Quality of Life and Health

For the group of small farmers, one has found important indications of the potential of the rope windpump to increase food production, provide more water, and generate more income. The

availability of sufficient domestic water has a positive effect on the general health and hygiene situation in and around the house.

12.2.8 Institutional Support

The development of the rope windpump in Nicaragua has benefitted strongly from the long-term support by external institutions from the Netherlands, as well as from other countries, such as Belgium, and Spain, which provided technical assistance and credit facilities:

- DGIS
- SNV
- DOG/PSO
- NOVIB
- OXFAM
- INTERMON

However, of the many National institutions in the country that could support the development and dissemination of the rope windpump, up to now only a few have actually been involved. One also concludes that there is a lack of knowledge and information at all levels.

13. RECOMMENDATIONS

13.1 General Recommendations

The rope windpump is one system -out of a range- designed and produced by AMEC in Managua around the concept of the rope pump. It is a promising pumping technology with the potential to generate income and increase the quality of life for several groups of end-users, in particular the small farmers. Basically, it is the flexibility of the rope pump concept that opens the way for the rope windpump -as it also does for the other pumping systems. It is therefore recommended to support the further development and dissemination of the rope windpump in Nicaragua and other countries in Latin America, preferably as part of a "package" of possible pumping solutions with the rope pump concept in common. Depending on the conditions and applications in the receiving country, the accent and methods of promotion may vary.

To achieve a further promotion and implementation of the rope windpump (and other rope pump systems) in and outside Nicaragua, additional external assistance will be inevitable as the local counterparts generally have insufficient resources available. This has become clear during the first transfers carried out within the framework of this project. It is therefore recommended to hook up with the existing support and promotion efforts for the rope handpump, and extend their reach to the field of larger water volume applications for which the windpump may be an attractive solution.

Currently, the basis for further dissemination of the rope windpump in Nicaragua is rather small. It is therefore recommended to strengthen the basis by developing a plan-of-action for Nicaragua, which should cover the next steps to be taken and could be developed jointly by the rural development and water supply experts active in the country.

It is recommended that a selection of small farmers be monitored over a longer period in order to obtain more information about the potential economic benefits of the rope windpump. To this purpose, a limited survey could be executed to obtain information on a full year of operation by the organisations CESADE or ENLACE, following the methodology used during this mission. Such monitoring may help CESADE to integrate the rope windpump more effectively in its rural development programmes and provide important data for further implementation programmes.

13.2 Recommendations on Specific Aspects

13.2.1 Technology

It is recommended to further support the technical development of the rope windpump in Nicaragua to:

- consider the specific requirements of each user group and adapt the standard model to better satisfy their needs
- develop a vane operating system that can be operated from the ground. This would also encourage women to use and operate the rope windpump. Such systems exist (a.o. in the Sri Lankan Niva-3000) and could be implemented in the rope windpump
- improve the quality of several construction details, such as: locking of nuts; vane arm connection; support for pump shaft and rotor blades

- develop a satisfactory system for electricity generation, whether as a combined water-electric system or as a separate windcharger based upon the rope windmill

Apart from the standard rope windpump model, it is strongly recommended to further support:

- the improvement of the more versatile AMEC “multigiratorio” rope windpump, by reducing or avoiding the transmission rope running off the top pulley
- the design of an alternative, more universal transmission system

13.2.2 Manufacturing by AMEC

In general, monitoring of the rope windpump manufacturing by an independent Quality Assurance Institute will enhance the product quality. It is therefore recommended to apply such a method.

With regard to AMEC, it is recommended that the workshop:

- improves its after-sales services and promotion in remote areas
- seeks for financial and technical support for the adaptation and further improvement of its rope pump products

There is no ground to expect that funding for this purpose will become available within the country itself; therefore support from abroad will remain necessary.

13.2.3 Credit Schemes in Nicaragua

With respect to the existing credit schemes in Nicaragua, it is recommended to:

- better adjust to the actual situation
- apply realistic payback times
- cover the acquisition of a full pumping system, not just the windpump
- reinforce more strictly the payback terms for the clients

13.2.4 Strengthening the National Basis

It is recommended to improve the existing support for the rope windpump in Nicaragua by:

- raising the awareness among relevant institutions; potential clients; financiers; rural development agencies; schools and universities
- preparing specific promotion material for each of the target groups
- creating an atmosphere of co-hesion and collaboration among the several development organisations involved
- establishing a “Plan- of-Action” for further improvement and dissemination
- promoting the rope windpump as part of running development project (such as the Leon-Chinandega project and CESADE’s Trópico Seco project)

13.2.5 Experiences and Applications

Regarding the early stage of development of the use of the rope windpump, it is recommended to:

- accurately monitor the current and future implementation programmes, with a focus on small-scale irrigation by the small farmers
- organise regular (for instance yearly) workshops or seminars to exchange information

13.2.6 Dissemination in Latin America

With respect to the dissemination of the rope windpump technology in Nicaragua, it is recommended to:

- promote the rope windpump as part of a range of pumping solutions, all having the rope pump in common
- start with those technologies, which most likely will have a market in a target country. Where conditions are comparable to Nicaragua, transfer of the rope windpump is certainly worthwhile; if conditions are significantly different however, one should be very cautious¹.
- strengthen the relations between regional organisations with an interest in producing and promoting rope pump technologies
- develop a "Plan-of-Action" for the region by involving experts and interested parties, such as: international and donor agencies; regional development organisations; financing agencies; and potential manufacturers
- follow-up and further support the four transfers executed as part of this project
- channel new requests for transfer via organisations participating in the "plan of action", in order to address them effectively

A similar approach can also be adopted to transfer the technology to countries outside the region (in the first place, with English as a working language).

¹ The Dutch 12PU500 windpump developed in The Netherlands for low wind regimes and pumping heads, was adopted by India. Three thousand machines were spread all over India -also in heavy wind regimes; most of them were totally blown away. In Bihar, where wind conditions are more favourable, the 12PU500 is still in use and even manufactured.

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