LESSONS FROM A PV PUMPING PROGRAMME IN SOUTH MOROCCO.

Luis Narvarte and Eduardo Lorenzo
Instituto de Energía Solar
Ciudad Universitaria s/n 28040 Madrid, Spain
e-mail: navarte@ies-def.upm.es
Tel: 34 91 5441060
Fax: 34 91 5446341

Mohamed Aandam
Association Tichka
9A Av. Mohamed VI, Ouarzazate, Morocco
Tel.-Fax 2124884398

ABSTRACT

This paper presents the experience of a PV pumping project being carried-out in the South of Morocco since 1997. At present, the project has reached 18 villages, affecting 15000 people. Total involved photovoltaic power is 46 kWp, and the total volume of pumped water since the installation of the systems approaches 0,7 x 10^6 m^3. About half the PV systems are based on dedicated inverters, while the rest are based on standard frequency drivers. Both perform very similarly in terms of both efficiency and reliability. Wells have been selected to provide good water taste, and pumped water is distributed to all the individual houses. Average daily water consumption in summer varies from 13 to 50 l per person depending on ease of water access and "urban proximity". The maintenance infrastructure is based on an agreement between the European supplier company and a local NGO, which is in charge of all the local organizations.

INTRODUCTION

This paper presents lessons learned during a PV pumping project implemented in the provinces of Ouarzazate and Zagora, a semi-desert region in the south of Morocco. Starting in 1997, the project has now reached 18 villages, affecting 15000 people. In all the villages water is first pumped to a storage tank 10 m above the ground, and then distributed to all the individual houses. Each house is provided with a tap and a water meter. There are no physical restrictions to water consumption, but progressive water tariffs are being applied. The total PV power involved reaches 46 kWp, and the total volume of pumped water approaches 0,7 million cubic metres.

Dedicated AC/DC converters (the well known Grundfos type) and also so-called Standard Frequency Converters, FC, are being employed. FC are mass-produced devices for general driving of standard AC motors (the global FC market is about US$ 5 billion per year). They can directly link PV generators with standard submersible centrifugal pumps[1], so they represent a PV pumping alternative within the reach of general PV installers. As far as we know, this paper represents the first long term experience of PV-

FC reported in the open literature. Moreover, full-tank detection is accomplished by means of a buoy at the tank and a spring valve in the exit water pipe of the well. This combination avoids signal wiring between the tank and the inverter, which represents an advantage if they are separated by long distances.

The project is being systematically evaluated. Pumped water is recorded daily at each village, and water consumption is recorded monthly at each house. This way, water consumption patterns are surveyed. Also, any exceptional event is carefully analysed. Particular attention is being paid to reliability aspects: reason for failures, repair delays, and so on. Organizational aspects are also being considered in the light of the long-term sustainability of the systems.

From a holistic viewpoint[2] a 'technology' has three components: a 'hardware' aspect, consisting of the tool that embodies the technology as a material or physical object; a 'software' aspect, consisting of the basic information for the tool, i.e. the methods and procedures needed to use the hardware efficiently (user know-how and behaviour); and an 'orgware' aspect, comprising the organization which allows individual users to get and maintain the service and which provides possibilities for interaction between the technology system and other relevant systems (installer companies, banks, etc.). This paper's presentation adopts such a viewpoint.

PV solar pumps are widely considered as reliable products[3]. However, it must also be recognized that their practical implementation still faces significant problems. Unfortunate situations are part of the realities in the field of PV rural electrification. For example, half of the approximately 500 PV pumps installed in Morocco are currently out of operation[4]. Therefore, feedback from in-field experience is still needed to improve PV engineering practices. This is just the motivation of this paper.

PRELIMINARY CONSIDERATIONS

The south of Morocco traditionally suffers large difficulties in water supply, leading the populations to be extremely conscious of water value and water use. This represents an obvious advantage for the implementation of PV pumping projects, because they address user priorities, and pave the way for real user involvement.

Traditional water supply combines two different systems associated with different water uses. On the one hand, there is water for direct human consumption: drinking, brewing tea, cooking and washing dishes. On the other hand, water is needed for other general uses such as personal hygiene, cattle drinking, and watering of small gardens. The user's criterion for well selection differs for these two water systems. Water taste is of paramount importance for human consumption (tea being largely associated with hospitality and prestige); while minimum human effort is the key aspect for other general uses. Typically, every village uses a single well for human consumption, which might be some kilometres away from the houses, whereas for other applications several wells are used simultaneously. Based on field observations, our estimates of traditional daily water consumption corresponding to each system in summer are 10 and 20 litres per person, respectively. While the first figure appears general (for example, similar consumption values have been found in the Brazilian Amazonia[5]), the second one hides a wider variety of situations and its estimation is much more difficult.

These are interesting considerations for PV design: water taste and human effort can be considered as the main parameters for calculating water pumping requirements. In our project, wells have been selected (in close agreement with the local populations) solely on the basis of best water taste, with taps inside the houses to minimize the human effort for water transportation. Thus, the PV pumps provide enough water to replace the two previous systems, and a daily consumption hypothesis of 50 l per person has been assumed for PV sizing.

It is worth mentioning that predictions of water consumption involve much uncertainty. The so called Regional Solar Programme (RPS) in Sahel countries forms a good illustration. This project is among the greatest standardization efforts ever made in the PV field. It has installed 616 solar pumps[6], all designed to provide two standard daily water consumption values: 20 l per person and 40 l per head of cattle. Subsequent evaluations make clear that "*In reality, these standards are rarely verified. In this way, in Burkina Faso, the observed consumption is only 10 litres per person per day. The consumption in terms of drinking water is not a statistic data. It varies with time, and depends on numerous parameters: the characteristics of the offer and in particular of the distance between the houses and the water distribution points; the existence of alternative water points; the villagers' awareness of the interest of the water service; the demographic growth of the village; and the season. »6*. The experimental water utilisation factor (defined as the ratio between actual water consumption and the originally expected value) varies from 17% to 93%6[,7,8,9,10]. Therefore, the optimization of water consumption values for PV design remains an open question deserving further investigation, and we hope our present observations are helpful.

The selection of water sources on the basis of best water taste often means pumping from traditional wells accessing shallow aquifers, rather than standard boreholes[11]. This requires protection against lack of water at the pump (shallow aquifer often means also weak aquifer, particularly in drought periods), and also against rubbish (traditional wells generally have large pitheads).

PV rural electrification within International Aid Programmes often divides responsibilities between foreign donors (typically supplying and installing the PV pump equipment) and national partners (typically in charge of local infrastructure including water sources, storage tanks, distribution pipe-work, housing, and fencing). This tends to ignore the real difficulties of local infrastructure in remote areas[12]. Again, the RSP provides a relevant example : "*Numerous technical problems (sizing, design, ageing, etc.) have been observed on the water distribution networks at the storage tank or at the fountains.15% of the villages of Senegal have reddish coloured water ; 15% also have a water pressure which is too low or problems of wear at the valves or other plumbing elements. Identical results have been recorded in Mali, with almost 30% of the villages having either water leaks at the tap heads or wear problems with the fittings. These problems have a direct impact on the water service proposed to the villagers and so on the image of all the solar pumping concept*»6.

General maintenance also remains an open question in PV rural electrification[13,14,15,16,17,18,19,20]. In particular, reliability data from real experiences are very scarce in the literature, making it difficult to prepare and set up professional organizations.

IN-FIELD EXPERIENCE

Table 1 shows the main characteristics of the PV pumps. The total PV power reaches 46 kWp, and several pumps have been in operation for more than seven years. The project initiative is by Tichka and Cipie, respectively a Moroccan and a Spanish NGO. The main source of financing has been by European Aid[21]. User participation has consisted of the provision of manpower for all civil works, which has been of particular importance because the project includes the water distribution pipe runs (over 3 km in some villages). Moreover, they fully paid for in-house infrastructure (including taps and water meters), and are routinely paying for water consumption. Regional water authorities helped to sink the wells and erect storage tanks. The Instituto de Energía Solar (IES) entered the project in 1997, mainly for evaluation purposes. Major aspects are:

Location	Population	Water head (m)	PV power (kWp)	DC/AC converter	Year of installation	Water pumped (m^3)	Relevant incidents
Oum Erromane	1250	55	3,7	Dedicated	1997	93990	Corroded pipes
Iferd	800	54	3,7	FC	1997	54210	Burnt out DC/AC converter. Corroded pipes
Abdi	550	47	3,0	Dedicated	1997	39390	Corroded pipes
Ait Mersid	960	49	3,0	Dedicated	1997	58500	Lack of water in the well
Tizguine	1940	31	2,2	Dedicated	1999	49225	Lack of water in the well
Tamsahalte	1200	62	2,2	Dedicated	1997	53580	Pump jammed by a wire.
Ourika	500	42	1,5	Dedicated	1997	15125	Lack of water in the well.
Bouzergane	2000	42	3,0	Dedicated	1997	38375	Lack of water in the well
Ouaougloute	430	60	2,2	FC	1997	23075	
Isdaouen	500	65	2,2	FC	2000	28800	Corroded pipes
Touna N'Iaraben	700	46	2,2	Dedicated	1997	45815	Corroded pipes
Zaouite Sidi Ahmed	150	25	0,7	FC	1997	12245	Corroded pipes
Imzoughen	1080	75	5,3	FC	1997	50935	
Taghzoute	400	81	3,0	FC	1998	26730	One broken PV module
Idermi	380	80	2,2	FC	1999	30805	
Hmam	240	35	0,7	FC	1999	7625	Lack of water in the well
Fint	700	50	3,0	FC	2001	21275	Lack of water in the well
Adghess	900	32	2,2	FC	1997	36270	Corroded pipes
TOTAL	14694		46			685970	

Table 1. Main characteristics of the PV pumps.

Hardware

At present, the total water pumped approaches 0,7 x 10^6 m^3. This indicates good general performance of the PV pumps. By far the most acute problem has been the scarcity of water in 2003. A prolonged drought caused the water table to fall. Additional deepening was performed in several wells, also requiring wiring and pipe-work modifications. Although this did not present technical difficulties, management of unforeseen situations is never easy within the framework of Aid projects. Hence, in the case of traditional wells, it is strongly recommended to anticipate well deepening in the initial project design.

In addition, two significant failures of PV equipment have been recorded. In one case a motor-pump was jammed by a wire after 8 months of operation. Most probably, the wire fell down into the well during construction of the curb well, just before the installation of the PV system. Later on it was sucked into the motor-pump and passed through the filter because the wire section was very thin. Whatever the cause, simple removal of the wire restored the motor-pump to proper operation. Obviously, the detection and solving of this problem required to pull-out the motor-pump from the well and to reinstall it again, which was much more expensive that the wire removal. This example clearly shows the need to avoid the entering of waste products into wells. In the second failure an inverter burned out.. We have not been able to identify a particular reason for that. The inverter was substituted by a new one. All together, the PV pumps included in this project have now (March 2004) accumulated 1350 months of operation. The repair cost of these two equipment failures reached about 3000 Euros (20% equipment, 80% travelling expenses and manpower), which represents no more than 0.4 cents per m^3.

The project includes two types of DC/AC converters, which differ in basic operation. The Grundfos ones are dedicated inverters, specifically designed for PV pumping. But the Omron ones are standard frequency converters, FC, (also referred as Variable Frequency Drivers, VFD, or AC drivers), used as general AC motors drives, adapted by internal programming to this particular application. Both perform similarly in terms of efficiency and reliability, and the installation and maintenance costs have been equivalent. The burned out inverter was a FCs type, but a single failure is statistically meaningless for estimating reliability. It must be noted that both types of inverter are protected against overcurrent, overvoltage, overheating, lack of water at the pump and full storage tank. In these two last cases, reconnection of the pump is delayed one hour, in order to avoid undesirable switching oscillation. One hour is a reasonable time for allowing water recovery at the well, and also water emptying at the storage tank.

It is also worth mentioning that protection against full storage tank is accomplished by means of a ball-cock and a spring valve. When the tank becomes full the ball-cock automatically locks the water inlet, causing the water pressure to rise suddenly inside the entire pipe between the pump and the storage tank. This pressure increase activates a spring valve, which provides the stop signal for the inverter. This trick avoids the installation of signal wiring between the tank and the well, which has been the classical solution for such protection. However its implementation is troublesome when the tank is far from the inverter. In the village of Iferd, they are 3 km apart.

Problems of water infrastructure quality have also been recorded. Firstly, serious corrosion appeared in some of the pipes built into the storage tanks. Such pipes are supposed to be made of galvanized iron and had been directly acquired at the local market and installed by the villagers. In some cases pipe removal required perforating and sealing again the base of the tank (see figure 1), causing up to one day service interruption. Secondly, we have heard a rather curious anecdote. Villagers believe that wells must "breathe" And in order to allow such breathing, they opened skylights in some well housing roofs. In the case of figure 2, the skylight was just over the well mouth, causing bird droppings to fall directly into the well (birds ran away when the photographer entered the well housing, but the skylight grille had been covered by them just a moment before). It is worth commenting that people living in rural areas have many technical skills since they have to build their own houses and manufacture their own working tools. Making the most of such skills for housing and installation works, and using locally available materials, are two of the best ways of encouraging local involvement. However this must go together with technical advice and help in order to avoid situations like the ones described above.

Figure 1. Corroded pipes at the base of a storage tank. Fissures were big enough to accommodate the knife blade.

Figure 2. Skylight allowing bird droppings to fall into the well

Finally, the cost of the hardware can be analysed considering the cost of a each pump. For example, the cost of a 2256 Wp PV pump, in the framework of a programme of 20 pumps, that pumps 30 m^3 per day to a height of 40 m, has cost 53460 € (that is to say, 23,7 €/Wp). The distribution of the costs of this PV pump is the following:

- PV modules: 8600 €
- Inverter + Pump + tube to water tank: 2330 €
- Transport and installation: 4058 €
- Local Infrastructure (well, water tank, and house for well and inverter): 23550€
- Distribution tube (average length of 900m): 4530 €
- Connection to the houses (average quantity of 50 houses): 5500 €
- Engineering: 2634 €

The consideration of all the pumps leads to a project cost of 22,2 €/Wp (or in terms of service to 24,6 €/m^4) as can be observed in figure 3 where it is compared with RSP costs. The distribution of the real costs of both programmes (considering the well, the water tank, the tubes, etc) allow us to conclude that the strictly PV part (modules, inverter and pump) is much less important, in terms of cost, that the part associated to decentralised electrification (transport, installation and local infrastructure). It is worth to mention that local labour and management have been excluded of this analysis.

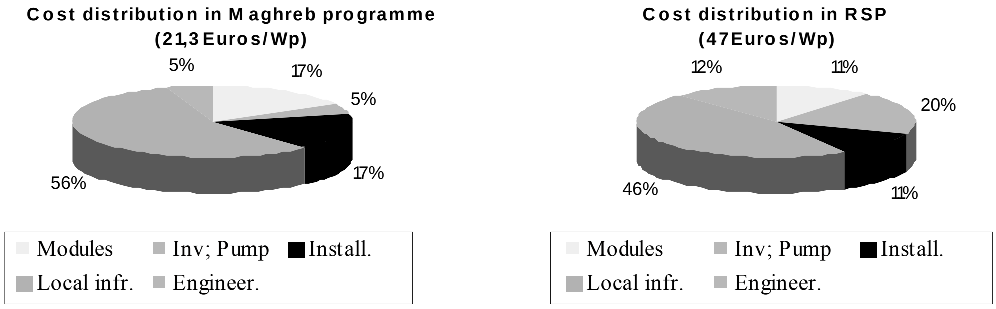

Figure 3. Distribution of the total cost in Maghreb programme and in the RSP.

Software

Figure 4 shows the evolution of water consumption in the typical village of Iferd. Pronounced seasonality is evident. Figure 5 presents the current average water consumption in all the villages. Ranges of 15 to 30 daily litres per person in winter, and 20 to 50 litres per person in summer are a rough description of the general situation, which is recommended here for PV sizing purposes. To a great extent, variability inside these ranges can be explained by considering the "urban proximity" of the villages. The more isolated a village the better preserved the traditional way of life and the lower the water consumption. The comparison between Iferd and Ait Mersid is a good example:

Travelling by car from Iferd to the closest big village (Nkob), where a common market of consumer products exits, takes at least one hour on a main road and an additional hour on a desert track. Moreover, public transportation is not available. However, a main road and regular public transport make it very easy to travel from Ait Mersid to its closest big village. Not surprisingly, Ait Mersid looks more modern (more domestic appliances can be often found, etc.) and annual daily average water consumption is larger than in Iferd, 37,8 and 32,8 litres per person, respectively (53,3 and 38,4 litres per person in summer). It is also worth commenting on the case of Bouzergane. During the first year of operation, its water distribution was restricted to a communal fountain for the whole village, and annual daily water consumption was equivalent to 17,2 litres per person. This is typical of difficult water access requiring significant human effort. This data is consistent with experimental observations of other authors: 10 to 15 litres daily per person when each watering point serves 250 inhabitants[22], and 10 to 20 litres when water sources are 300 meters distant[23].

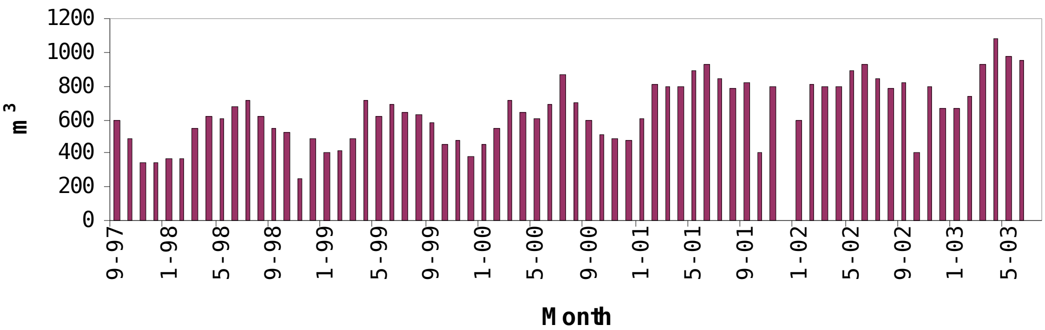

Figure 4. Evolution of water consumption in Iferd.

These examples (that are summarised in table 2) suggest that water consumption is mainly influenced by ease of access , and urban proximity. The first parameter is imposed by the PV project design, while the second one can be guessed by analysing transport facilities. Combining both concepts, the PV engineer can get a guide for an adequate estimate of water consumption for PV sizing purposes.

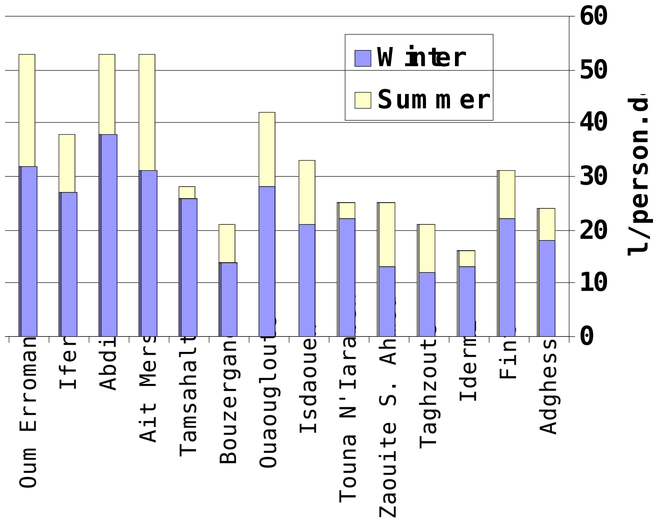

Figure 5. Average water consumption in winter and summer in PV pumping systems in the south of Morocco.

Village	Date of installation	Water consumption (l/pers.day)		
		Summer	Winter	Annual
Iferd (ease of access to water and urban remoteness)	Sept-97	38,4	27,5	32,8
Ait mersid (ease of access to water and urban proximity)	Oct-97	53,3	25,4	37,8
Bouzergane (difficulty of access to water)	Ago-97	20,9	13,8	17,2

Table 2. Comparison of average water consumption in winter and summer for some representatives villages of the programme.

Orgware

PV pumping should encompass water payment, in order to cover the costs associated with long-term sustainability of the service. Usually, a local "Water Committee" is in charge of money collection, while maintenance is (or should be) the task of an external organization with adequate technical skills and availability of spare parts.

In this project, different villages apply different tariffs (see table 2). In all the villages the tariff comprises very progressive rates, and money is routinely collected without major problems. Somewhat surprisingly, we have not observed any relation between water tariff rates and water consumption. Apparently, populations are still very conscious of the value of water. Traditional solidarity prevents non-payment. For example, widows are excused payment, and the rest of the villagers pay for them. Traditional solidarity also prevents over-consumption. For example, in most villages, construction of new buildings has been forbidden during summer months, in order to avoid using water for cement during periods of water scarcity. This is of particular importance in this area, because there are a lot of emigrants in Europe who return for summer holidays, and many of them would like to build new houses. Not less important, traditional solidarity prevents against PV modules robbery. In most villages an effective continuous surveillance service is provided in turns by all families on a rota basis.

Village	Fixed rate	First tranche	Second tranche	Third tranche	Fourth tranche	Period of payment
Imzoughen	10,00	From 0 to 10 m^3: 2,00 dh/m^3	From 10 to 20 m^3: 4,00 dh/m^3	From 20 to 30 m^3: 4,00 dh/m^3	More than 30 m^3: 5,00 dh/m^3	1 Month
Taghzoute	5,00	From 0 to 5 m^3 : 20,00 dh/month	From 5 to 40 m^3: 2,00 dh/m^3	More than 40 m^3 : 3,00 dh/m^3		1 Month
Fint	10,00	From 0 to 10 m^3: 3,00 dh/m^3	More than 10 m^3: 5,00 dh/m^3			2 Month
Hmam	1,00	From 0 to 10 m^3 : 2 dh/m^3	From 11 to 19 m^3: 3,00 dh/m^3	More than 20 m^3 : 5,00 dh/m^3		1 Month

Table 3. Water consumption tariffs applied in different villages.

Collected money covers daily expenses (metering, periodical tank cleaning, administration, etc) and maintains a local fund for the future common good of the community and for the maintenance of the PV pumping system. Water committees are being encouraged to keep a bank balance of at least 10000 Dirhams (approximately 1000€), in case a motor-pump or an inverter need to be replaced, and this is effectively being done in most villages. Typically, annual collected money ranges from 12000 to 35000 Dirhams per village.

It should be stressed that user payments in this project largely cover long-term maintenance costs. However, linking user economic capacity with a professional organization, able to assure maintenance, still remains an open question. Two technicians from Tichka, the Moroccan NGO, have been trained by Isofoton, the PV systems supplier, and are now able to repair most failures. However, an NGO structure is not appropriate for assuming long-term technical responsibilities. Therefore the future constitution of a company, able to operate in the free market, is now being considered. The small regional PV market is the main obstacle because such a company would have to maintain, say, three persons and a car, which requires a minimum annual turnover of about 100000 €. Obviously, this can not be justified by the few interventions presently required by the project. However, the Moroccan PV scene is now very dynamic, partly due to the huge SHS markets launched by the National Electricity Office, ONE[24]. We hope that internal synergies will rapidly provide the critical PV market size to justify the existence of a fully professional PV company in this region.

CONCLUSIONS

Experience acquired in a PV pumping project carried out in the south of Morocco over more than seven years has been presented. The following lessons are considered of general value:

1- Standard Frequency Converters perform similarly to dedicated converters in PV pumping systems, providing that adequate protection is implemented in both cases.

2- Supplied pumped water satisfies two requirements: its taste is good, because the wells have been carefully selected; and access is easy because it is distributed to all the individual houses. Good water taste and ease of access represent improvement from user's point of view, and are key parameters for user acceptation of PV pumping technology. In these conditions, daily water consumption typically reaches 30 to 50 l per person during the summer months (depending on urban proximity).

3- Users pay regularly for their water, and the collected money covers maintenance costs. However, a professional maintenance organization needs significant enlargement of the corresponding market.

Acknowledgments

The authors would like to acknowledge the support provided by the European Commission, under the project "Best practices for PV water pumping and purification programs (POMPAPUR)" (contract DG TREN: NNE5-2000-35).

References

[1] Alonso M, Lorenzo E,Chenlo F. PV Water Pumping Systems Based on Standard Frequency Converters. *Progress in Photovoltaics: Research and Applications* 2003: **11**:179-191.
[2] Dobrov GM. Systems assessment of new technology for decision making in government and industry. *IASA (International Institute for Applied Analysis) Internal Report* 1997, Vienna.
[3] Drouart E, Vouillamoz JM. *Alimentation en eau des populations menaces*. Hermann Editeurs des Sciences et des Arts: Paris, 1999.
[4] Nasir El Hak R. Expérience Marocaine dans le Domaine du Pompage par Énergie Solaire Photovoltaïque. *Proceedings of International Seminar "PV water pumping and potabilisation in rural areas", European Commission*, Ouarzazate, Morocco, 2003.
[5] Fedrizzi C. *Sistemas Fotovoltaicos de Abastecimiento de Agua para Uso Comunitario: Liçoes Apreendidas e Procedimientos para Potencializar sua Difusao*. PH.D. Thesis, Universidade de Sao Paulo, Brazil, 2003.
[6] Liebard A.. *Regional Solar Programme. Lessons and Perspectives*. Fondation Energies pour le Monde, Paris, 1999.
[7] Gay B. Le coût de l'eau solaire au Mali. *Proceedings of the Workshop on PV Water supply System Improvement (STR/1229/97-DE)*, 1998, Marrakech, Morocco: 59-66.
[8] Kaboré F. Le programme régional solaire: hydraulique villageoise et pompage solaire au service du développement durable dans les pays du Sahel. *Proceedings of the Workshop on PV Water supply System Improvement (STR/1229/97-DE)*, 1998, Marrakech, Morocco: 13-25.
[9] Hänel A, Hoang-Gia L, Kaboré F, Sy B.S. The performance of PV pumping systems in the CILSS-Regional Solar Programme: One year of monitoring results on 10 systems. *Proceedings of 13th European Photovoltaic Solar Energy Conference*, 1995, Nice, France: 482-485.
[10] Hänel A, Hoang-Gia L. Monitoring of representative PV pumping systems of the Regional Solar Programme: results and conclusions. *Proceedings of the Workshop on PV Water supply System Improvement (STR/1229/97-DE)*, 1998, Marrakech, Morocco: 85-90.
[11] Boreholes use to drill deep aquifers, whose salt content tends to be relatively high due to the large time that water remains in contact with rocks.
[12] Lorenzo E. In the field realities of some PV rural electrification projects. *Renewable Energy World*, 2000: **3**, (5): 38-51.
[13] Luque A, Hegedus S. *Handbook of Photovoltaic Science and Engineering*. Wiley, New York, 2003.
[14] Nieuwenhout FDJ, Van Dijk A, Van Dijk VAP, Hirsch D, Lasschuit PE, Van Roekel G, Arriaza H., Hankins M., Sharma BD, Wade H. *Monitoring and evaluation of Solar Home Systems. Experiences with applications of solar PV for households in developing countries*. ECN-C-00-089, Netherlands Energy Research Foundation ECN, Petten, 2000.
[15] Lorenzo E, Zilles R, Caamaño E. *Photovoltaic rural electrification. A fieldwork picture book*. PROGENSA, Sevilla, 2001.
[16] Hankins M. A case study on private provision of photovoltaic systems in Kenya. *Energy Services for the World's Poor, ESMAP*, World Bank, 2000: 92-99.
[17] Lorenzo E. Photovoltaic rural electrification. *Progress in Photovoltaics: Research and Applications* 1997: **5**: 3-27.
[18] Huacuz J, Martínez AM. Renewable energy rural electrification. Sustainability aspects of the Mexican programme in practice. *Natural Resources Forum* 1995: **19**: 223-231.
[19] Fabris A. "Participation and involvement of the state in decentralised rural electrification programs", *International Seminar of Sustainable Development of Rural Areas* 1995, Marrakech: 89-96.
[20] Vallvé X., Ruiz JM, Serrasolses J. Organisational scheme for multi-user stand alone PV/Diesel systems implemented in villages in Spain, *2nd World Conference on Photovoltaic Solar Energy Conversion*, 1998, Vienna: 3445-3448.
[21] Contract ONG/PVD/1995/974/CSR. Programa de Abastecimiento de Agua, Fomento de Salud y Formación Sanitaria, Valle del Dra'a, Marruecos. *European Comisión – DG08*, 1995.
[22] Hoang-Gia L. Revue des programmes d'approvisionnement en eau potable par pompage photovoltaïque en Afrique de l'ouest. *Proceedings of the Workshop on PV Water supply System Improvement (STR/1229/97-DE)*, 1998, Marrakech, Morocco: 45-50.
[23] Sada B. Conditions de viabilité des projets d'hydraulique solaire photovoltaïque. *Proceedings of the Workshop on PV Water supply System Improvement (STR/1229/97-DE)*, 1998, Marrakech, Morocco: 55-58.
[24] ONE's PERG Programme ("Programme d'Electrification Rurale Global") plans to provide electricity to 840000 inhabitants (150000 dwellings) of decentralised rural areas: www.one.org.ma (April 2004). When this paper is being written there is a tender dossier for the installation of a total of 37000 PV individual systems.