Mainstreaming Renewable Energy Technologies into Mexico's Agricultural Sector
Reflections on the FIRCO/Sandia Pilot Project, 1994-2000

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Executive Summary

From 1994 to 2000, a pilot program was undertaken by FIRCO (an agency of what was then SAGAR) to introduce renewable energy technologies into Mexico's agricultural sector. The pilot project selected, as a focal technology, photovoltaic[1] water pumping systems for livestock watering on off-grid rural ranches. During the pilot project over 200 such systems were installed in 13 Mexican states, and these projects achieved three goals: (a) to create awareness and interest in the technology on the part of ranchers, (b) to encourage the development of local companies that could supply quality equipment and services, and (c) to enable FIRCO to develop a team of engineers and technicians with the knowledge and experience needed to successfully implement future projects.

The success of FIRCO's pilot effort was evident in the decision by Mexico's government to have FIRCO implement a full-scale nation-wide program and by FIRCO's success in securing the resources to do so. FIRCO's nation-wide Renewable Energy for Agriculture Program was begun in 2000.

The pilot effort provided evidence that renewable energy technologies are worthy of investment, and that they can and should be mainstreamed into Mexico's agricultural sector. The experience also cautioned that success required attention to detail and attention to the lessons learned, both positive and negative. But the pilot also brought into focus an area of major concern, the rural finance sector. We perceived the lack of access to rural financing as a fundamental limitation to the program's efforts. Stated positively, the expanded use of renewable energy technologies in

[1] The photovoltaic effect results in the direct conversion of the sun's light (photonic energy) into electricity. Photovoltaic modules are the commercial enabling product.

Mexico's rural sector is dependent on a healthy rural finance sector and on the development of specific financing mechanisms.

FIRCO Takes on PV Water Pumping, 1994 to 2000

From 1994 to 2000, under the auspices of what was then SAGAR and in the context of the successive programs of the Solidaridad and Allianza para el Campo, FIRCO and a Mexican/US team[2] of solar energy technologists carried out a pilot program whose goal was to help mainstream the use of proven and cost-effective renewable energy technologies for agricultural production.

The aims of FIRCO's pilot program were aligned with a broader FIRCO objective, which was to improve agricultural productivity through the application of modern technology. There were at FIRCO's disposal a range of proven commercial renewable energy technologies (RETs) that could provide thermal, mechanical and electrical energy[3] for agricultural activities. These technologies were (and continue to be) a competitive choice in off-grid settings where the use of fossil fuel alternatives is costly or difficult. FIRCO and the Mexico Renewable Energy Program (MREP) team selected a single renewable energy technology, water pumping systems powered by photovoltaic modules, as the application they would pursue. Two reasons led to that choice. First, PV water pumping was a technically mature and cost-effective option. Second, the technology matched perfectly with the needs of the ranchers – a reliable means of providing water for cattle at very low operational and maintenance costs.

The pilot program's approach was straightforward. In each of the states where the pilot program was carried out[4], the MREP team partnered with the FIRCO state agency's engineers and program director, assisting them in the effort to develop their capacity to use commercial PV water pumping systems. A handful of PV water pumping projects were quickly implemented on active, producing ranches, and in each of these first projects, the MREP experts provided training to the FIRCO engineers and to local PV equipment vendors. Following the first demonstration and training project in each state, the state FIRCO team immediately developed their own first batch of PV water pumping projects and executed them with assistance from the Sandia team members. This enabled the FIRCO engineers to master the entire sequence (defining a project, determining its feasibility, sizing the system, developing specifications, bidding the project, evaluating bids, performing an acceptance test, and monitoring, over time, the systems performance.)

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[2] The US/Mexican team, which operates the Mexico Renewable Energy Program, receives its funding from the Mexico mission of USAID and from the U.S. Department of Energy. The team effort is managed by Sandia National Laboratories and includes a number of U.S. and Mexican professional consultants (contract personnel) plus the following organizations: Mexico's Asociación Nacional de Energía Solar, (the National Solar Energy Association); the Centro de Investigacion en Energía, UNAM (Center for Energy Research (UNAM)); Winrock International; Sandia National Laboratories; the Southwest Technology Development Institute, and the National Renewable Energy Laboratory.

[3] Solar thermal applications include (but are not limited to) desalination of water, drying of crops, heating and cooling of buildings, and cooking. Photovoltaic applications include water pumping, electric fencing, and modest quantities of electricity for other productive applications. Wind applications include water pumping and community electrification.

[4] First Chihuahua and Sonora; and then Quintana Roo and BCS. At the culmination of the pilot effort, projects had been carried out in 13 Mexican states.

Thus, the pilot projects provided training for FIRCO staff and local PV equipment vendors and served as visible demonstrations throughout ranching communities that allowed ranchers to test the technical and economical utility of the systems. The pilot effort, if successful, would allow FIRCO to institutionalize their use of PV. Their use of renewable energy for other productive applications would be expected to follow[5].

By fiscal year 2000, the Mexico Renewable Energy Program[6] had installed 206 photovoltaic water pumping systems throughout 13 states in Mexico (Baja California Norte, Baja California Sur, Chiapas, Chihuahua, Coahuila, Jalisco, Morelos, Michoacan, Oaxaca, Quintana Roo, San Luis Potosi, Sonora, and Veracruz). Several wind water pumping projects were also carried out. In the course of implementing these projects, the program had provided practical training to well over 1,000 engineers, government officials, university students and professors, and PV systems vendors throughout the country.

Toward the end of the pilot period, FIRCO and the MREP team began to lay the groundwork for an expanded FIRCO program. They secured the resources and support for a nation-wide effort that became FIRCO's Renewable Energy for Agriculture Program (Programa de Fuentes Renovables para la Agricultura). This US$31[7] million dollar program, which began in the latter part of 2000, is targeting the cattle ranching industry in states all over Mexico where wind and photovoltaic water pumping systems have a significant market opportunity.

The Pilot Program Paved the Way And Taught Important Lessons

The pilot project succeeded, inasmuch as FIRCO decided to go forward and expand this program at the national level. The team learned important lessons both from their successes and from their difficulties. In the execution and in the aftermath of the pilot, the team would summarize their experience as follows:

- Renewable energy technologies are worthy of investment. They can and should be harnessed more extensively for agricultural production in Mexico.
- The keys to success lie in attention to details, in attention to key program elements such as partnering, training, capacity building, education, replication, and technology adaptation. Care is also required to help rather than hinder the market.
- Financing is one of the barriers between RETs and many in the rural population, and the resolution of problems in Mexico's rural finance sector could facilitate a noticeable increase in the use of RE in the coming decade in its agricultural sector.

Renewable Energy Technologies are Worthy of Investment

[5] For example, milk cooling for rural dairy operations.
[6] A small fraction of these PV water pumping projects were carried out in partnership, not with FIRCO, but with other organizations with whom the Sandia team worked during the same six-year period.
[7] $30M in the form of a World Bank loan and $1M as a grant from the Global Environmental Fund.

The pilot program offered proof that PV technology works well in Mexico's rural sector and enhances productivity. Evaluations of the projects that were implemented gave evidence that in many off-grid ranches, PV pumping systems are a cost-effective, reliable option with unique and advantageous features. Several case studies provided evidence that these systems may very well increase profitability.

Cost-effectiveness of the PV water pumping systems as compared to "motobombas" is linked to whether the PV systems have lower operation and maintenance costs – sufficiently low to offset their higher initial cost. PV systems have no fuel or fuel transportation costs and generally have longer intervals between replacement of components. The preliminary data and its analysis (Rochin Garces, 1998 and Strachan, 1999) suggest a significantly lower life-cycle cost (in Spanish you might translate the phrase '*...an overall lower cost over their useful life*.') for PV water pumping as compared to gas powered pumping for hydraulic loads in the general range of 50 to 500 m^4, in off-grid rural settings Baja California Sur, where fuel, fuel transportation, and engine maintenance costs are relatively high. This same result could be expected in many other off-grid regions of Mexico.

Other evidence of the greater positive economic value of using PV pump systems came from ranchers themselves, who expressed a liking for their performance, particularly the fact that they operated in an unattended mode, which simplified the logistics of livestock watering. Certainly, there were a large number of ranchers and ejidos that applied to be included in the pilot program. Applicants in Sonora, for example, exceeded the project's capacity by a ratio of approximately 10 to 1 or more. More convincing evidence of the PV pump systems greater value came after the projects were completed, through questionnaires completed by system owners. A survey of 20 of the 206 PV pump system owners (adjacent figure) indicated a high degree of owner satisfaction. These results are consistent with other indications that the PV systems have had satisfactory performance and reliability. Nonetheless, the survey was not performed independently but by project team members, and independent verification would be valuable.

Customer Satisfaction with Photovoltaic Water Pumping Systems (Richards et al, 1999)

	Excellent	Good	Average	Bad
Convenience	77%	23%	0%	0%
Reliability	82%	18%	0%	0%
Performance	95%	5%	0%	0%

The fact that there was very significant market growth for PV pump systems provided a separate and more independent indicator. Market growth suggests, at minimum, that ranchers believed that the PV pump systems would increase their profitability, or would simplify their ranching operations, or perhaps both. Information from two PV system vendors in Sonora provided concrete data of the market growth, a pattern that was also observed in other states:

A successful PV system vendor/installer in Hermosillo, Sonora provided sales data indicating that his sales/installations of PV water pumping systems had grown noticeably, in the range from 50% to 100% per year in the 1997 to 1998 time period, the period following FIRCO/Sonora's first 20 demonstration projects. However, this data is unqualified in that the vendor's accounting system was rudimentary or partial.

This vendor, in a personal interview[8] made the following observations:

- The experience he gained selling and installing some of the PV pump systems purchased through the program increased his technical capacity.
- The demonstration projects provided proof to ranchers that the systems worked well. The demonstration projects allowed the systems to be installed and gain a good reputation.

A second Sonoran vendor, one who participated relatively little in the FIRCO pilot program, provided more detailed sales information in January 1999. He reported a total of more than 700 sales of PV water pumping systems in the time period from 1994 to 1998 and a growth in sales during the years 1995, 1996, 1997, and 1998 of 81%, 42%, and 85%, and 74%, respectively. His sales were was predominantly to customers, as best we have determined, who did not receive (probably did not apply for) the subsidy available to them under the *Alianza para el Campo program*.

The pilot effort provided valuable lessons about what worked well.

It was not a surprise to see that technical details were critical to success. A key goal of the pilot team was to insure that the water pumping systems were properly sized and designed, used optimal components, and were installed according to best practices. Beyond installation, during their operational life, it would be important to monitor system performance and to insure that qualified local service and supply of components remained available.

Capacity building proved an effective means to this goal, a prime vehicle that moved the program. It required partnering among FIRCO, the US/Mexican PV technologists, the local PV industry, and the ranching community. The capacity to use PV water pumping technology successfully was achieved with practical training courses, which were held in conjunction with the first PV projects in each region. Each "first" project was a PV water pumping system installed on an active, productive ranch in the target region. The value of this approach was that it allowed us to target the training of the local PV industry, and the FIRCO engineers, while at the same time promoting the new technology with ranchers in the area. The FIRCO team members and the PV vendors/installers learned or improved best practices (in design, equipment selection, and installation) from PV systems experts. Both obtained hands-on experience that prepared them to do future projects.

This direct experience obtained by the FIRCO engineers and PV vendors in each state as they implemented groups of projects was essential to the capacity building. The FIRCO staff prepared the RFQs (the bid document and the request for quotation) in which were included strict technical specifications provided by the MREP team. The vendors responded competitively and FIRCO, with assistance from the PV experts, evaluated and selected the best offers. The systems were installed by the vendors and then turned over to the owners after acceptance testing by the FIRCO field engineers. Over time, FIRCO was able to monitor the systems in the field, and to help insure that the local industry was responsive to the O&M needs for the systems. In this overall process, both FIRCO's technicians and the local vendors came up to speed relatively quickly. The process

[8] The author held this interview in late 1996 and transcribed his notes into electronic form in January, 1997.

worked well to identify and resolve problems that arose (and, as in any human endeavor, problems did arise.)

Education was another key. Since ultimately the decision to use PV water pumps was a market decision, the education of the buyer was essential. We were successful in "getting the word out" about PV water pumping through the end-user organizations, the cattlemen's associations, and the events they themselves sponsored (such as the 'feria ganaderas'). Both the intermediate users of the technology (e.g., FIRCO and other large institutions) and the ranchers learned, in the pilot program, the value and the range of applicability of PV water pumping. They became aware of critical issues affecting their decision to buy or not to buy. PV water pump systems are not always the best choice. Some commercial systems are not suited to specific needs. Acceptable local services and supplies are not available everywhere. Potential users of PV water pump systems sometimes have unrealistic expectations. Sometimes the most preferable options are overlooked. Sometimes PV pump technology is chosen merely because of its novelty. In summary, the pilot program sought to provide true advocacy for PV water pumping, to avoid overselling the technology, and to demonstrate its appropriate and valuable role.

The efficiency and success of the pilot effort would be measured in the long run by successful replication, i.e. the degree to which the projects implemented led to or facilitated numerous other similar projects. The successful collaboration between FIRCO and the US/Mexico team of RE technologists did encourage other public agencies to increase their use of renewable energy technologies. There were numerous examples of this. One of them was water supply for small rural communities. We choose to mention it because it is a critical need in Mexico and elsewhere, and one that has been difficult to meet. The sustainability of potable water systems in small rural communities and the local ability to organize socially and to generate the resources to obtain and operate these systems, is a serious challenge. But FIRCO's successful pilot effort in water pumping means that there are now human and institutional resources in Mexico that could be leveraged to the task of rural community water supply. And there are successful models and experiences in the region that show that remote rural communities can organize, take ownership and responsibility, and manage PV-powered water systems in a sustainable fashion (Graham, 2000).

Finally, technology adaptation and innovation was also observed to be a powerful ingredient for success. In BCS, FIRCO engineers and technicians enthusiastically took the PV water pumping system concept and integrated it into a model for a sustainable desert ranch. The water pumping component was sized to provide both water and emergency supplies of fodder for cattle (using small-scale drip irrigation), thereby reducing losses to their herds during times of draught (sequía). Their model of the sustainable, PV-powered ranch (Rochín Garcés, 1999 and 2000) led BCS state agencies to funded numerous projects independent of the pilot program, and demonstrated that technology adoption and innovation can greatly enhance the economic value of the technology and increase profitability.

The pilot program also offered lessons in terms of what we found difficult to accomplish.

The lessons we learned from our difficulties were perhaps the most valuable: monitoring installed systems is critical; nurturing the supply infrastructure for equipment and services is vital; a proper relationship between our program and the PV industry is essential. Moreover, beyond these lessons, we saw that our efforts involved a certain risk of hurting rather than helping the market for renewable energy technology.

We knew in advance the importance of monitoring the performance of installed systems, but perhaps we underestimated the cost and difficulty of doing so. Significant and scientifically defendable results were obtained in this regard, but more work is needed. The MREP is, in fact, undertaking additional work to further evaluate the impact of the pilot effort.

We had success in creating a viable service/supply infrastructure in many states, but in several instances, the program's deployment of commercial systems out-distanced the service/supply infrastructure and we saw problems such as systems that were improperly sized or installed or systems that did not receive maintenance or repair in a timely fashion[9].

We were more successful in encouraging the growth and maturation of PV vendor/installer networks than for wind water pumping. In part this was due to the fact that fewer wind pumping projects were implemented. FIRCO's current program is increasing the emphasis on wind energy and is using a regional focus for this part of its efforts – by implementing its first group of projects in a single region of Mexico, an approach that will facilitate the development of a solid local wind industry.

At the outset we understood the importance of maintaining the proper relationship of our work to the marketplace and to work with, not against the market. This effort to simultaneously increase the number of ranches employing PV water pumping while helping rather than hindering the development of the PV pumping market proved to be a challenge. Even though all the pilot program's purchases were done competitively, some vendors expected or experienced being isolated from the opportunities to participate from the multiple purchases. Some large distributors of equipment expressed criticism that the program, in its effort to speed the development of a service/supply infrastructure in a given state, was interfering with their own market development in that region or state. At the same time, other distributors and vendors successfully obtained a market advantage in the process, extending their own network of representatives and distributors.

Beyond these issues was the fact that ranchers and ejidos who purchased systems through the pilot program obtained one, sometimes two, subsidies: the normal subsidy offered by Solidaridad and Alianza during those years, plus an additional subsidy offered by the pilot project itself (using funds provided by the US government). As a result, some owners participating in the pilot program paid only 10% of the cost of the PV water pumping systems. During the latter part of the pilot (1998 to 2000), the buyers of most of the pump systems paid in the range of 50%. Such subsidies can be justified as necessary in that they encouraged ranchers to experiment with a technology that was new and perhaps riskier. But some critics argue vehemently that subsidies such as these have a negative long-term effect on the market--that many potential buyers are discouraged from buying PV pump systems at the full price when some ranchers and ejidos are

[9] Reports from team members such as Arturo Romero, Ecotourismo y Nuevas Tecnologías, Mexico, D.F.

obtaining them at a fraction of their true price. Certainly the FIRCO/Sandia goal of deploying and demonstrating the technology was facilitated by the use of subsidies; they enabled us to deploy several hundred PV water pumping systems across Mexico. But were the middle and long-term interests of the market for PV water pumping technology served? The discussion that follows, financing in the rural energy sector, provides a window through which to view this issue.

Financing Renewable Energy: Bottleneck or Floodgate?

Two factors relating to rural financing combined to create a fundamental external limitation to the pilot project. The first was the higher initial capital cost of RETs as compared to fuel-powered options. Although we were convinced that in many cases PV water pumps would have the lowest life-cycle cost, many ranchers could not overcome the higher initial capital cost except through subsidies, financing, or some other mechanism. The weakness of Mexico's rural financing sector during the years of the pilot program left us with subsidies as the only mechanism readily available to put PV systems into the hands of the those who could not purchase them for cash, so that was the path we followed. In retrospect we can see that the pilot projects brought a lot of attention to PV pump technology, created a large demand, and that the demand quickly exceeded the capacity of the Alianza program.

One obvious solution was to find financing or other mechanisms that would increase the access to capital to a larger segment of the rural population, hopefully the economically disadvantaged. However, the pilot program encountered serious difficulty when it pursued this solution on behalf of ranchers participating in the program. Interest rates were high. Many ranchers had already defaulted on prior loans. Many ranchers and ejidos were unfamiliar with, unaccustomed to, or distrustful of credit. We reached the unhappy and ironic conclusion that credit was only a viable alternative for those who did not need it.

Ultimately, our pilot effort was unable to solve this underlying problem. What we did instead was launch a small pilot financing project, one that would demonstrate that financing can work in the dissemination of the RETs. This pilot financing effort was carried out in Chihuahua where a a small loan fund was capitalized (Ojinaga et al, 2000).[10] The pilot financing activity was well worth the effort, but, at the end of the day, the fundamental issue remained unresolved and, even at the time of this writing, the development of a healthy rural financing sector in Mexico remains a key task, an inherent barrier.

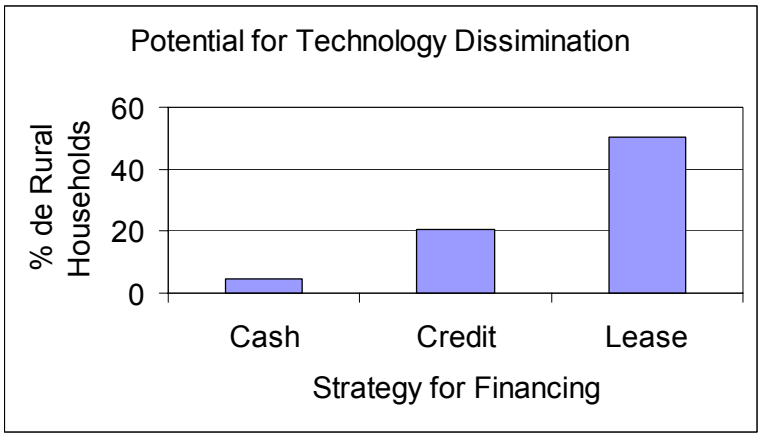
There are Financing Solutions for Rural Renewable Energy.

The work of others in Central America, the Caribbean[11], and elsewhere in the world is demonstrating that the number of rural people able to acquire energy services increases as various

[10] This effort was led by Chihuahua groups including FIDEAPECH (el Fideicomiso Estatal Para el Fomento de las Actividades Productivas en el Estado de Chihuahua and Chihuahua's Working Group for Renewable Energy (El Grupo de Trabajo de Energia Renovable), a multi-agency collaboration together with the Sandia team.

[11] The accompanying table is based on a graph developed by Global Transition Group, Enersol Associates, and SOLUZ, 55 Middlesex Street, Suite 221, Chelmsford, Massachusetts, USA, 01863 (Tel: 978-251-1525). The first three categories in the graph shown here (cash, credit, and rental) are based on data gathered by and the direct experience of these three organizations.

mechanisms for the purchase of energy systems (or of energy services) are made available in the rural marketplace. This premise is sustained by a growing body of literature. Access by the rural population to energy services, including those derived from renewable energy technologies, will increase as the range of available financing mechanisms is increased, as the set of options grows beyond cash purchase to include financing mechanisms like credit, fee-for-service, and rental[12] (Kaufman, 2000). In Mexico, where mechanisms like these do not yet exist, this same conclusion, this same limitation, this same challenge, is applicable.



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[12] The percentage values reflected in this table come directly from the first-hand experience and market research with PV powered systems in rural villages of the Dominican Republic and Honduras of Global Transition Group, Enersol Associates, and SOLUZ (55 Middlesex Street, Suite 221, Chelmsford, Massachusetts, USA, 01863. Tel: (978) 251-1828).

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