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Alternative Power Sources
Final Project Report

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Executive Summary

Educational radio is being used in many developing countries to improve educational quality without greatly increasing the cost of instruction. Although a great effort has been made to keep continuing costs low, there are still some necessary on-going costs that cannot be avoided. One cost that is troublesome because it is such a large part of continuing costs is the cost of providing power for classroom radio receivers. Because classroom radios need fairly large speakers, their power requirements are correspondingly high. The cost of this power is high because most schools in developing countries, especially those in the poorest rural regions, do not have utility power but must instead use batteries, which may cost as much per year as the radio cost.

There are a number of alternatives to battery power: solar power, crank radios, pedal power (using a bicycle-like apparatus as a generator), and so on. The Alternative Power Study was undertaken by the Radio Learning Project to investigate alternatives, especially solar power. Although solar power for radios has been discussed as an alternative for years, and even tried in several sites, it is only recently that the cost has decreased enough to make this a genuinely feasible alternative.

The Alternative Power Project experimented with a number of configurations of radios and solar panels. Two panels were found that promised to work well with the GE SuperRadio, a radio that is being used as a classroom radio in several countries, including the Dominican Republic and Honduras. Since, apparatus that works well in the laboratory may not work as well in actual practice, a field test was planned. Honduras was selected for on-site testing of the apparatus. Eight typical rural schools in three different climate zones in Honduras were selected as test sites. A solar panel was installed on the roof of each school, with a lead going down to the radio. The radio could be unplugged from the solar panel when desired. Thus, the radios could be moved about, but the solar panels were fixed.

Both configuations that worked well in the laboratory were used in the field tests. The sites were visited twice, once for initial installation and once, several months later, to see how well the equipment was working. Besides inspecting the apparatus itself, teachers were asked to express their experiences and feelings about the use of solar power.

Both solar panels worked well, but it was clear that the large panel was ~~most~~ more acceptable to teachers. Those who had the large panels reported a higher degree of satisfaction with battery life (before recharging) and with sound quality. The situation in Honduras is unique in one way: the teachers themselves own the radios. The radios do not belong to the schools and are not ordinarily kept in the schools, but are carried back and forth from home to school by the teachers who own them. There are two consequences of this: First, the radios are unplugged from the solar panels at the end of the school day, which is usually very early in the afternoon; consequently, the batteries were not charging during some of the peak sun hours (from about 10 AM to 3 PM). Second, the radios were used at home, on battery power only, for four or five hours a days. In this circumstance, the large solar panel was found to be more acceptable. In other places, where more of the peak sun hours would be used, or where the radios are not used so much on just battery power, the small panels would be a successful, and cheaper, solution.

One disadvantage of the large panel is that, with strong sunshine, it can deliver enough power to damage the radio. This needs further investigation but it is possible that a charger controller might be needed, which would add to the cost of the package.

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Introduction

The United States Agency for International Development has, for the last 15 years, been sponsoring the development of radio-based education in many countries. Both development and maintenance costs enter greatly into the decision of whether a country can afford the project or not, but the maintenance cost is usually the main consideration since it must be paid entirely by the host country. Power for radios in the classrooms is a major component of ongoing cost. Radios appropriate for classroom use have larger speakers and draw more power than other portable radios. Often teachers are encouraged to take the radios home (so they are not stolen from the classroom) and to use the radios after school. A typical teacher will use a set of batteries in 3 to 6 weeks, and this will, in most cases, cost more than the radio within the first year. For radio to gain widespread use in developing nations, the cost of powering the radios must be addressed. This report outlines the Radio Learning Project's investigative work in powering radios with solar (photovoltaic) panels.

The goal of the Alternative Power Project was to examine alternative power sources that promise to be both feasible and cost-effective. Our preliminary work involves photovoltaic energy sources (the conversion of sunlight energy into electrical energy). There are, however, many more possible power sources such as crank radios, wind-powered radios, and pedal-power radios. We started by investigating the potentially most cost-effective possibilities first. Pre-existing utility power will win hands-down every time against all other forms of powering the radios and should be considered for first use wherever it is found. Installation of utility power however is expensive and not feasible for most schools in developing nations. It is a good idea to keep in mind that radios should be bi-modal, having capability to run on either batteries or utility power. Because the cost of solar power has been rapidly decreasing, this seems to be the next best possibility. This report explains the solar test radio and the test results from a year of operation of eight field-test sites in Honduras.

This is the final report to be produced for the Radio Learning Project's Alternative Power Project. This report, in conjunction with the "Alternative Powers Sources Interim Project Report," gives a complete accounting of work done to test the feasibility of using solar power panels with classroom-size radios. This report includes the most important sections of the interim report with additions and modifications.

Proper Design – An Essential

An improperly designed solar-powered battery-recharging system can become less than cost-effective under some conditions. An important factor is the method used to recharge the batteries, which can dramatically alter the life of the batteries. The experimental radios were designed with two different sizes of solar panels to test for maximum battery life.

Solar Radio Design Basics

Specification of the radio's requirements and method of charger regulation was performed and yielded the following facts:

- 6 D cell NiCds require 8.1 volts for a slow recharge.
- Constant current could be up to 100 mA continuously.

Kyocera manufactures panels almost exactly to our requirements:

Panel	Voltage	Current	Dimensions
Miniature	8.1	87 mA	3" x 5.5" x 3/4"
Small	8.1	160 mA	4.25" x 6.25" x 3/4"
Large	8.1	328 mA	5" x 9" x 3/4"

For the field test we purchased three of the small panels and seven of the large panels so we could test both models in the field. Friend Dialogues has a sample of each panel type and has found that even the miniature panel is sufficient to power a radio for several hours a day. The miniature panel was not used in field tests.

There are two types of D cell NiCd batteries; one has a rated capacity of about 1.1 ampere hours and the other has a capacity of about 4.5 ampere hours. The cost difference is great, and since we plan for a daily recharging of the batteries, a capacity of 1.1 ampere hours is sufficient. For a perspective on this, a *GE SuperSport II* running at highest volume uses about 110 milliamperes. The radio would thus play for 10 hours on a fully charged set of batteries. A more likely situation is an average rate of only 30 to 40 milliamperes, giving a play time of around 30 hours. This seems quite sufficient for our needs. Another consideration is that the 4.5 ampere hour batteries can be charged continuously at a much faster rate, hence they could handle a much larger solar panel without fear of damaging the batteries.

The D cell NiCds fit conveniently into the same compartment as the original carbon zinc batteries. If we find that charger control circuitry is required, it could also be housed inside the GE radio itself.

Estimation of power requirements involves deciding the time span for operation (worst case) and the power required over that time. The following factors were decided on:

- Power required on average: 50 mA
- Hour use per day: 4 hrs.
- Days run per charge: 3 days
- Charging inefficiencies: 1.4

From this, a daily charge requirement can be calculated:

required daily charge = 50 mA x 4 hrs x 3 days x 1.4 = 840 mA-hrs

By research into the number of peak solar hours at the location of installation, daily charge times can be found. Honduras has a minimum of five peak sun-hours each day for charging. Experience shows that the teachers will begin school at 8:30 am, quit at about 12:30 pm, and take the radios home. This gives them four hours of charge time (solar panel is fixed on school roof), but these are not peak sun-hours. During non-peak hours the solar panel will provide power but at a reduced rate. From this, we estimate that we may get about three peak sun-hours per day. A simple calculation shows the required solar panel output.

Solar panel output = 840 mA-hrs/ 3 hrs = 280 mA

A panel that is rated at 280 mA is required to sufficiently charge the batteries. The above calculation will insure four hours of use per day for a period of three days after a one-day charge. This guarantees operation even during several days of bad weather.

There is a possible problem of overcharging the batteries. With fully charged batteries (1.1 amp-hr NiCd cells) it is not possible to put more than 110 mA through them without causing damage to the cells over time. The question is whether the batteries will ever be in this condition. If they are, it will most likely only be for three hours per day (four hours connection minus one hour radio broadcast time). A very high rate of charge such as 270 mA can be applied to drained cells without problem. A teacher who regularly drains the batteries at night may get longer life from the NiCds than a teacher who carefully uses the radio for only one hour per day.

To evaluate this in the field, one solar panel was selected that would supply the batteries for recharging at rates of around 200 to 320 mA, and another that produced 100 to 160 mA. The smaller panel will not produce as many hours of radio play per day but will not damage the batteries. The larger panel will provide much more play time, and we will see, over time, if it adversely affects the batteries.

In large solar applications the installation of the panels and batteries is important. Especially important is the orientation of the solar panel itself. It was decided that the field test units should be mounted with the best orientation possible to the winter sun, and yet have a flush easy mount on top of the school roof. In the eight test sites the panels were mounted flush with the school roofs on the side that received morning sunlight, a far-from-optimum orientation.

Most solar panels used for recharging batteries require electronic controllers to maintain the proper recharge rate, time, and duty cycle. This device is most important with lead acid batteries but also applicable to NiCds. NiCds can be charged much faster with a controller, and must be charged very slowly without one. To keep costs down, we did not use a controller. Figure 1 below shows the configuration of the solar radios used in Hondruas.

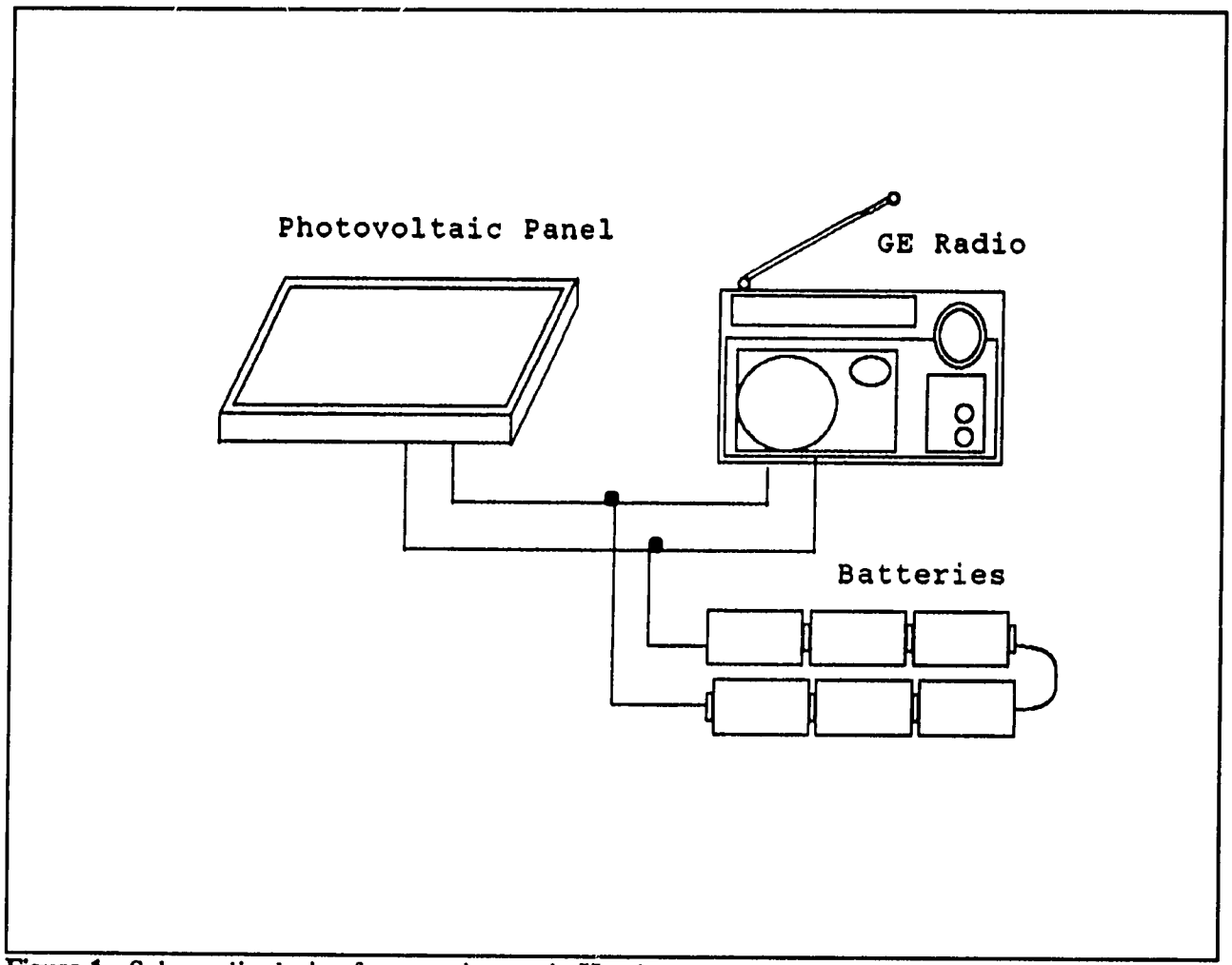

Figure 1. Solar radio design for experiments in Honduras

Criteria for the Design of Experimental Test Site Radios

The development of a combination radio and solar recharger has a large number of variables and options. Among the questions to be answered are non-technical ones such as the following:

1) How long should the radio play each day?
2) Can the panel be fixed on the school or must it be portable with the radio?
3) How much can the cost of the radio be increased?
4) How many days must the radio be able to play without recharge? (This depends on how many rainy days in a row are expected.)

Also, there are a lot of technical questions, many of which deal with cost trade-offs of functionality and feasibility.

The following list shows the major aspects of the test-site radios:

1) Use of the GE SuperSport II radio.
2) Six nickel cadmium D cells placed internally in the radio.
3) Modification to radio adding a connection for a power line from the solar panel.
4) Use of two types of solar panels from Kyocera:
   3 small panels 8.1 Volts 160 mA.
   7 large panels 8.1 Volts 328 mA.
5) Mounting brackets to allow flush mount on school roofs. This was a simple arrangement of two small hinges.
6) Lead-in wire and connectors to go from roof-mounted solar panel to the radio.

Experimental Test Plan

In order to gain information about potential problems of solar-powered radios, an experimental plan was developed to help uncover such problems. The experimental tests consisted of work at Friend Dialogues and also field testing of experimental radios in Honduras. After several weeks of development a suitable radio system was developed and field testing of eight sample units commenced. Schools were selected and eight field test sites were set up. During the installation a questionnaire was completed by the teacher. The solar-powered radio was explained to the teachers. During the first two months the teachers made daily entries in a log book. At the end of this time they were given another questionnaire. The radios were left in the schools as a test of longevity.

The schools were carefully selected (by the AVANCE evaluation team) to be typical of the country schools that are the key target for solar-powered radios. None of the schools selected had utility electrical power. The following three regions were selected (see Figure 2):

San Pedro Sula:	Hot, clear
Valle de Angeles:	Cloudy, misty most mornings
Danli:	Marginally hot, clear

Both sizes of solar-power panels were tried out in each of these three areas.

In each of the test sites the panels were mounted on the roofs and the power cable was run down into the classrooms. During the installation an evaluator from AVANCE described the radio's operation to the teacher and presented them with a paper that contained the same information.

Teachers were instructed not to replace the batteries in the radios and never to connect the radio to power sources except the solar-power panel. Also the teachers were warned not to connect other devices to the solar panel as its unregulated voltage could destroy those devices.

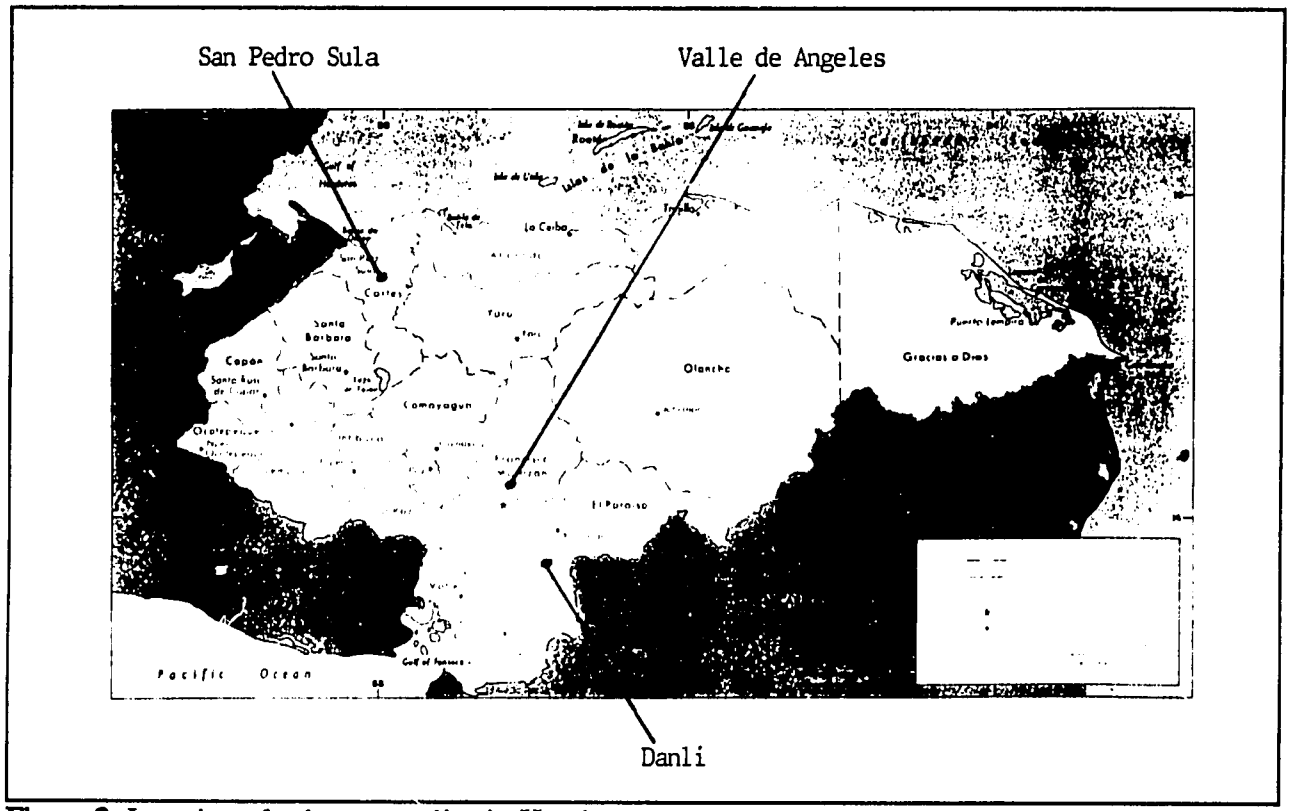

Figure 2. Location of solar test radios in Honduras

Experimental Results

During the installation of the radio a questionnaire was administered to the teacher. On a return visit several months later another questionnaire was given. During the first two months of the experiment, the eight school teachers made daily entries in their log--the amount of time the radio was used during the day, how long it was connected to the recharging solar panel, and the weather during the recharging period. In addition, there is a section on how well the radio worked that day and a space for teacher comment.

Preliminary Questionnaire Results Appendix A contains the questionnaire given to the teachers. Nine radios were installed in Honduras; eight in schools and one in the AVANCE SEI radio office. In the eight schools classroom security was marginal. Anything valuable could easily be stolen. Because of this, most teachers took the radios home each day. All schools did have locking doors and bars on the windows, and three of the eight teachers said they would feel safe leaving the radio in their classroom overnight.

Mounting the panels was an easy and quick task. The panels were mounted on the roof oriented to catch the morning sun, while maintaining a flush mount on the school roof. In any large scale installation, careful consideration should be given to the roof material in use in the host country. In Honduras we found steel, zinc, asbestos, and brick-like "teja" roofs. Mounting on each takes a different

approach and materials. The asbestos is strong but screws will strip out. Teja roofs cannot be walked on or drilled into. The steel and zinc roofs were the easiest to work on.

In the questionnaire, teachers responded that 'D' batteries cost between US $ 0.63 to $ 0.88 each. At this cost, a teacher would spend approximately US $ 60 to $ 84 per year. Cost estimates made in the next section are based on a $ 0.69 battery. For Honduras the cost savings could be greater if the average primary battery cost was higher than $ 0.69. Battery prices are the retail prices in Honduras and can be appropriately compared to a solar radio the teacher would buy. If we want to compare the cost with project-supplied solar radios, then we should be careful to consider that the projects might be able to purchase local batteries in qualtity for less than $ 0.63 per 'D' cell. Some teachers commented that they no longer brought their radios to school because they used up too many batteries.

Most schools have two grades per classroom but some had up to six grades. School hours were generally from 7:30 am to 1:00 pm, although three teachers worked 8:00 am to 4:00 or 4:30 pm. The hours a teacher works and whether the radio can be left in the classroom influences how long a radio can be charged each day with a solar panel fixed to the school roof.

Primary batteries lose voltage slowly as they are used up. NiCd batteries, on the other hand, maintain a constant voltage until almost completely drained. This difference in discharge produced different symptoms of drained batteries. In our survey most teachers cited low volume as a measure of dead batteries. Only one teacher listed poor reception and poor audio clarity as a measure of dying batteries. This situation could be a slight problem as few understood that their NiCd batteries were low on charge when the audio quality decreased. During final school visits several radios were getting poor reception, audio distortion, and poor bass response indicating they were in need of charging, but the teacher did not have them connected to the solar panels for charging as they should have.

Most teachers felt the radios were a good value, affordable, and well suited to their classroom use. The radios cost US $ 62.50 and only one teacher would have paid significantly more (twice the price) for a better radio. When asked how much more the teachers would pay for a radio that had batteries that never went bad, only four responded, and they wished to pay only US $12.00 to US $25.00 more. These same teachers are estimating their primary battery consumption (their estimated cost per battery and how often they change batteries) at US $65.00 to US $91.00 per year. Clearly their understanding of the issue is not complete, but possibly they cannot pay more than a small amount at one time making batteries an easier purchase. With the battery cost being 2% to 4% of the teachers annual income it is, in most cases, 10 times an average US home electric bill and a very important issue to the teachers.

Few teachers owned more than one radio. Also noted was the fact that few teachers were willing to bring in their personal radios for school use. During interviews, some teachers reported that other teachers would buy radios from the project only to take them home and not use them at school.

Extracurricular radio usage was quoted at an average of four hours per day. When asked for the time the radio was turned on in the afternoon and off at night the responses indicated that most would use the radio from four to eight hours extra each day. Weekend radio usage was from eight to 12 hours per day. All teachers said other family members used the radios and at higher volume than they themselves did. When asked about a radio that could only be used four hours per day, 75% responded that this was unacceptable. When asked if it was okay to have a radio that only worked if brought to school each day only 38% said this was unacceptable. 88% responded that they would <u>not</u> like a radio that did not function during school vacations. The fragility of the solar panel seemed to be

a neutral issue that the teacher seemed unconcerned about.

The questionnaire results showed that the teachers wanted a more portable charging system that allowed for more radio play each day. They would also have to be shown the economic advantage of solar power and possibly be allowed to pay for the radio and solar charger over time. For those teachers that leave the radio at school there seems to be no objection to the current arrangement of a fixed-mount solar panel.

Daily Log Summaries The teachers kept daily logs of radio usage during the first two months of the study. Most teachers did not completely fill in their daily log books. And the radio usage data conflicted to some degree with what teachers said on the final school visit. It was clear from the logs that the smaller panels caused trouble by discharging significantly on weekends and even on week days. The larger panels had far fewer incidents of discharge; only occasionally did they discharge on weekends, whereas the smaller panels regularly discharged on weekends. Daily logs showed that the teachers were very regular in their arrival to school and charging of the radios. The logs seem to be approximately in congruence with the results listed in the next section. Appendix B contains the daily log sheet form.

Final School Visit Summary After several months of operation seven of the schools were revisited and the radios tested. The radio in School #2 had failed. School #5 was closed when we visited it, and we were unable to interview the teacher. School #8 only connected the panel two days a week. The following questions were asked of the teachers in each school:

Panel:	Solar panel size?
Functional:	The radio functions correctly?
School:	How many hours a day do you run the radio in school?
Home:	How many hours a day do you run the radio at home?
Weekend:	How many hours a day do you run the radio during the weekend?
Poor Function:	Does the radio ever sound bad?
Died weekday:	Do the batteries ever lose charge during the weekdays?
Died weekends:	Do the batteries ever lose charge during the weekends?
Reconnect work:	When the batteries are discharged, on Monday mornings, does reconnecting the solar panel make the radio sound right?
Bad reception:	Does the radio ever have bad reception?
Continue:	Do you want to continue with the solar radio another year?

A summary of the data from the eight schools is shown in Table 1.

Inspection of the radios showed most batteries were rusted slightly. Also the connector that was installed on the radio for the connection of the solar panels appeared in poor shape. If a solar-power installation requires disconnection and reconnection daily then a much better connector system should be used. The radio in School #4 was dropped and the connector broken after a month and a half of operation; this radio was repaired and left in operation. All radios sounded good and no batteries looked as if they had vented and leaked electrolyte. Some teachers commented on the return visit that they would pay more for the radio and panel than their previous estimates.

Table 1
Data from Teacher Interviews

	Schools							
	1	2	3	4	5	6	7	8
Panel:	small	large	large	small	large	large	large	small
Functional:	yes	no	yes	yes	-	yes	yes	yes
School:	1 hr	-	1 hr	3 hrs	-	1 hr	6 hrs	2 hrs
Home:	2 hrs	-	2 hrs	3 hrs	-	2 hrs	6 hrs	3 hrs
Weekend:	-	-	8 hrs	6 hrs	-	6-7	12 hrs	12 hrs
Poor function:	yes*	-	once	yes*	-	once	once	no
Died weekday:	no	-	no	no	-	no	no	no
Died weekend:	yes	-	no	no	-	no	no	yes
Reconnect work:	yes	-	yes	**	-	***	yes	yes
Bad reception:	-	-	no	no	-	no	no	*
Continue:	yes	-	yes	yes	-	yes	yes	yes

- missing answer
* when batteries do not have a charge
** after an hour of connection it worked well
*** radio was never discharged to test re-connect

of

At the finish of the project there are two radios that have melting in the battery compartment; these are at School #2 and Friend Dialogues, both of which have the large solar panels. There are, however, two large panel radios that are known to be still working (after 16 months of operation). One of the functioning radios is connected continuously to its panel 24 hours a day (AVANCE SEI office radio) and one is connected only occasionally to its panel (a Friend Dialogues test radio). The battery compartment melting problem is a very serious one. Isolation of the problem is not easy. It may be a combination poor materials in the radio's spring wire and a lower internal impedance characteristic of NiCd batteries; thus causing excessive heat to be generated. The melting occurs when a spring wire in the battery compartment becomes excessively hot due, I believe, to excessive current flow. The spring wire then melts both the batteries and the compartment close to it. It is not known whether the excessive current flow is during battery charge or discharge (play). Another possibility is that the poor connection (press fit) spring wire and connection pad causes a very high resistance to be present at the connection, thus generating heat during charging periods (a possible 3.6 watts of heat). If this bad connection occurs during play then the potential is less since it is governed by the volume level of the radio to about 1 watt or less of heat. Another likely possibility is that the external solar panel connector was short circuited; this could theoretically produce hundreds of watts of heat for an instant causing arcing, burning, and melting. This potential of the NiCds make them considerably more dangerous than primary batteries.

Several cases of NiCd "memory" have occurred. This is when the batteries are charged and

discharged in a continuous and equal duty cycle that never fully discharges the batteries. When this occurs, the batteries remember their discharge level and refuse to discharge further. If NiCds are used in future projects then one of the newer NiCd designs should be used; the newer design essentially eliminates this memory effect.

Very recently AVANCE has reported that one school's radio was stolen, and another school had its solar panel stolen. Fixed mount solar panels may not be a good choice in countries where theft is likely.

Preliminary Cost Evaluation

Before any work was done to develop a solar powered radio, a preliminary estimate of costs was made. How much money is currently being spent on primary batteries in not exactly known but an estimate was made. The cost of primary battery usage was then compared to the cost of a solar-powered radio over a period of 15 years. Estimates for two levels of battery usage were considered, to give both a low primary battery cost and a higher primary battery cost. Keep in mind that solar and battery power can in no way compete with the very low cost of utility power. If utility power is in the schools then it should be used, and all radios should be capable of using it. Also note that the solar power panels used in this experiment are not likely to be cost-effective if the radio is used for only a half hour to an hour and a half per day. If radio usage can be limited then it may be possible to lower the solar radio cost greatly by using a very small portable photovoltaic panel that can be placed in a school window or doorway. The single biggest advantage of the larger panels (like those used in this field test) is the ability to play the radio and charge the batteries at the same time. This makes it possible to use the radio early on Monday mornings after the batteries have been completely discharged by home use over the weekend.

It should be pointed out before we go further that this is only a preliminary estimate, and as such should not be used directly to estimate cost saving for the mass distribution of solar radios. The next section lists some considerations for making a better estimate for a specific site.

An approximation of the cost of the solar powered radio was made. For now, neglect the cost of the radio, which will be purchased whether the unit is powered by primary batteries or by a solar-powered rechargeable battery. To calculate the cost of the solar-powered radio we looked at the primary cost factors and estimated costs for those items:

1)	Radio modification cost:	12.00
2)	Solar panel cost:	25.00
3)	School installation cost:	15.00
4)	Battery cost:	14.50
5)	Hardware cost:	7.70
	Total cost:	74.20

This amount gives us a radio of higher cost than the UN solar radio, which costs an estimated $72.00, including the radio. This makes our cost comparisons more conservative.

Breakeven cost, in our estimates, comes within the first 1.1 to 2.5 years of operation. Even if it takes 2.5 years to break even, the solar-power radios look very feasible, given that the life expectancy of the solar panels may be 10 to 20 years.

In the following examples we will use the (unconfirmed) lifetime of 3 years for the nickel cadmium (NiCd) batteries. Over 15 years, the battery replacement cost would be $72.50. Since one set of batteries is included in the original cost, the cost of replacement batteries is $58.00.

Cost savings over the life of the radio are harder to calculate given inflation and fluctuations in exchange rates, etc. However, a very simplistic calculation pits present cost of solar radios against total cost of primary batteries over the life of the solar radio; in our case, the estimated savings over 15 years for the GE SuperRadio II is $858.85. For a country with an installed base of 8,000 solar radios this comes to a nationwide savings over 15 years of $6.87 million. If we estimate more conservatively with less primary battery consumption, then the nationwide savings for 8,000 radios could be as low as $2.48 million.

If we were to estimate primary battery consumption at a mere $10.00 per year then the cost savings for the solar radios becomes nonexistent; that is, the solar panels would be more costly than primary batteries.

Calculating Cost Evaluations in the Future

Calculation of costs and savings over time is not easy. Many things can cause errors and when projected over many months and years they build up to be large cost errors. To avoid making mistakes two things have to be done:

1) Get *exact* cost for implementation.
2) Get *exact* information on current costs.

These two tasks are not easy, in fact almost impossible, but necessary if the estimates of cost savings are to be valid. The following list shows major cost areas for which to get exact estimates:

- Best possible primary battery cost--local batteries cost, not best US cost
- Remember battery quality and hence life may vary from one local brand to another
- Solar panel cost in quantities
- All mounting hardware costs
- Local nickel cadmium battery cost, for replacements after initial setup
- Radio modification costs
- Delivery and installation costs
- Administration cost; spread out over all radios
- Good estimate for NiCds' battery life expectancy; varies with recharge method
- Lowest possible primary battery usage attainable at the site under consideration

Recommendations for Further Studies

It is apparent that the cost savings over the life of a solar-powered radio recharger is tremendous. The hard-to-quantify aspects of solar recharging are its usage limitations, such as the fixed location of the recharger and the need to recharge every few days during heavy radio use. Also, several questions are hard to factor into an equation of economic gains, such as, who will pay for the solar-radio rechargers

and installation, and who now pays for the primary batteries? How do these questions affect the cost-effectiveness of implementation of a large scale solar-radio installation?

The next step in the evaluation of solar radios should be the careful design of a solar radio and the negotiation of production of this radio in quantities suitable for a large scale applications. Then produce several hundred test radios for application in a host country. The host country should preferably be one with exceptionally high primary battery cost or poor access to replacement batteries. The preliminary experiments showed that only the smaller solar panel was suitable for applications without a charger controller.

More work is required before we have a clear idea of the cost benefits, but it is clear that for any host country that has limited access to primary batteries or very high primary battery cost that the solar radios would produce great cost savings.

There are five remaining solar radios in the test site schools of Honduras. It is hoped that they will remain and can be evaluated yearly to gain more information on the solar radios' longevity.

Appendix A

Teacher Questionnaire

RADIO USAGE QUESTIONNAIRE

** PREREQUISITES:
- Bring pens.
- Bring this form.
- Bring a GE radio with batteries.
- Bring a writing surface/clipboard.

** Oral presentation: We would like to know more about radio usage by our teachers. For us to know this, we must ask you a few questions. We are trying to find out if we can provide a less expensive means of powering the radios than with regular batteries, and your help would be appreciated. First, let me tell you that we will not use the information you give us to evaluate you personally. No one will know how you answered the questions. We will put all the teacher's answers together to find out how much most of the teachers use the radio. Please be as precise as possible when answering the questions.

o How long have you been using the radio lessons?

o Do you like the radio lessons?

o Do you think your students like the radio lessons?

o Do the radio lessons help your children learn?

o Is buying batteries for your radio expensive?

o How often do you have to buy more batteries for your radio?

o How do you know when you need new batteries?

o Do you like the school radio?

o Does the radio play loud enough for your classroom?

o Does the radio sound good at classroom volume?

o What did you pay for your radio?

o Was this too expensive?

o If you had a choice would you have bought a cheaper radio even if it were not as loud or clear-sounding as this one?

o Was the purchase of the school radio a financial problem

for you and your family?

o If the radio cost twice as much but was better, would you have been able to purchase one?

o At home do you usually listen to AM or FM stations?
AM_____
FM_____
BOTH____

o What type of radio do you have:
GE SuperRadio II_____
Radio Shack/Tandy_____
Other_____

IF other:
- Please specify brand:_____
- Is this your personal radio?_____

o Do you own more than one radio?

IF YES:
- Do you sometimes switch which radio you bring to school?
- Do you usually bring to school the radio you bought from the school officer?

o How long do you play the radio in the classroom each day?

o Do you leave the radio on in the classroom at low volume for most of the day?

o How loud do you play the radio during lesson broadcasts?

o How many hours a day do you listen to the radio outside of the classroom?

o Normally what time do you turn on the radio for classroom use?

o Normally what time do you turn the radio off after the lesson?

o At what time do you (the teacher) usually arrive at school?

o At what time do you (the teacher) usually leave school for the day?

o Usually at what time after school do you turn the radio on for pleasure?

o Usually at what time do you turn the radio off for the night?

o Please show us the radio station you usually listen to at night.
(Have teacher select station on radio.)

o Turn the radio to the volume you normally have the radio after school.
(Test radio with sound level meter.)

---

o Do you usually leave the radio at this volume or change the volume during the day?

Please put the radio on the volume you use most of the time.
(Have teacher set the volume.)

(Test radio with sound level meter.)

---

o How many hours a day do you play the radio VERY loud?

o How many hours a day do you play the radio at medium volume?

o How many hours a day do you play the radio very quiet?

o During Saturday and Sunday how much do you play the radio per day?

Saturday_____

Sunday_____

o On Saturday/Sunday do you usually play radio louder than usual?

Louder_____

Same_____

Quieter_____

o Do your spouse and children use the radio often?

IF YES:

- How many hours a day do they use it?

- What days a week do they use it?

- How loud do they play it?
  Louder than you_____
  Same as you_____
  Quieter than you_____

o What time do you come to school in the morning?

o What time do the children come to school in the morning?

o What time does the radio broadcast start?

o Do you own a wrist watch?

o Do you ever arrive at school just before the radio lesson starts?

IF YES:
- Does this happen:
  Often_____
  Some_____
  Rarely_____

** Now we would like to ask you a few questions about the weather in your area. This is weather for an entire year, so please keep in mind both the rainy season and the dry season.

o Is it ever cloudy for entire days?

IF YES:
- How many days a year?

o Are there ever times when it is cloudy and raining for many days in a row?

IF YES:
- What is the longest number of cloudy days in a row?

o When it is rainy or cloudy, are the clouds around all morning

long (during the school day) or do the clouds only come a few hours a day?

- All day:_____
- Few hours:_____

o Does your school get direct sunlight in the mornings?

o At what time in the morning does the sun directly light the roof of your school?

o At what time in the morning does the sun directly light the ground around your school building?

o Are there lots of tall trees around your school building.

IF YES:
- Do these trees cast shadows on the school in the mornings?

o What is the roof of your school made of:
Wood:_____
Tin:_____
Tile:_____
Asphalt tiles and gravel:_____
Other:_____

o What are the walls of your school building made of?
Brick:_____
Cement block:_____
Wood:_____
Concrete:_____
Other:_____

o Does your classroom have electricity?

IF YES:
- Do you use your radio on wall outlets (electricity) at school?
- Do you ever use battery power even when at school?

o Does your home have electricity?

IF YES:
- Do you use your radio on wall outlets (electricity) at home?
- Do you ever use battery power even when at home?

o How much do you pay for a set of batteries?

o How many batteries does your radio use?

o How much does one battery cost?

o What is the cheapest you have paid for a battery?

o What is the most you have paid for a battery?

o Do you have a choice in the brand/kind of battery you buy?

IF YES:
- What brands are available?_____

_____

- What types are available?_____

_____

- How much do the very expensive batteries cost?

o If we could sell you a set of batteries that would last forever, how much would you be willing to pay?

o If this set of batteries that lasts forever would only work every day for 4 hours, would this be okay with you?

o If this set of batteries had to be taken to school 5 days a week to work right, would this be okay with you?

o If this set of batteries only worked during the school year and not during vacations would this be ok with you?

o If this set of batteries was put in a breakable glass box that had to be taken to school and home each day, do you think that you could keep it from breaking?

- Would you prefer this breakable set of batteries

in a separate box, or would you rather buy batteries?

Batteries:_____

Box:_____

o How do you get from school to home each day?

Walk_____

Drive car_____

Taxi_____

Bus_____

Motorcycle_____

o Do you now take your radio home each day with you?

o Do you take anything except the radio home from school?

IF YES:

- In what do you carry your other things home?

Appendix B

Teachers' Daily Log Book

DAILY LOG BOOK

DATE:_____ DAY:_____

Time at which the radio was connected to the solar charger:_____
Time at which the radio was disconnected from the charger:_____

Was it cloudy or rainy in the morning? Yes____ No____
Was it cloudy or rainy in the afternoon? Yes____ No____

Time at which the radio was turned on for school use:_____
Time at which the radio was turned off after school use:_____

Volume level in the school: low___ medium___ high___ very high___

Time it was turned on at home:_____
Time it was turned off at home:_____

Volume at home: low___ medium___ high___ very high___

Did the volume go down on the radio as if the batteries were dying? Yes____ No____
Was the sound loud and clear during the lesson? Yes____ No____

****

DAILY LOG BOOK

DATE:_____ DAY:_____

Time at which the radio was connected to the solar charger:_____
Time at which the radio was disconnected from the charger:_____

Was it cloudy or rainy in the morning? Yes____ No____
Was it cloudy or rainy in the afternoon? Yes____ No____

Time at which the radio was turned on for school use:_____
Time at which the radio was turned off after school use:_____

Volume level in the school: low___ medium___ high___ very high___

Time it was turned on at home:_____
Time it was turned off at home:_____

Volume at home: low___ medium___ high___ very high___

Did the volume go down on the radio as if the batteries were dying? Yes____ No____
Was the sound loud and clear during the lesson? Yes____ No____