Country Project Report: **Tuvalu**

**BACKGROUND**

Tuvalu is one of the smallest, poorest and least developed countries in the world. It has a total land area of only 25 km$^2$, an exclusive oceanic economic zone of 900,000 km$^2$ and a 1991 population of 9,043. The land area, which consists of three small reef islands and six atolls, is small even by low island standards with land formations ranging from 0.4 km$^2$ (Niulakita) to 5.6 km$^2$ (Vaitupu). Land elevations throughout the archipelago rarely exceed 4 metres above mean sea level. The islands are poor in natural resources, possess a low level of biological diversity, and has one of the world’s more fragile and vulnerable ecologies. Forty-three percent of the population is concentrated on the island of Funafuti, the country’s administrative centre, while the remainder of the population lives in single village settlements on the eight outer islands.

**ENERGY IN TUVALU**

Tuvalu’s base of presently developable, commercial scale indigenous energy resources is very limited, restricted exclusively to solar and biomass (primarily coconut husks, coconut shells and wood). Imported petroleum accounts for about 40% of gross, primary energy consumption — a percentage share that is rising rapidly. The balance is contributed by solar and biomass. With Diesel generated electricity on Funafuti and with the provision of solar photovoltaic electrification on the outer islands, 71% of Tuvaluan households have access to electricity for basic household use. Of the 984 outer-island households, 39% (386) utilised lighting powered by solar photovoltaics in 1995. Even on the main island of Funafuti, there are rural areas without power and 11 households have opted for photovoltaic power. In 1994, there was a waiting list of approximately 180 households which had requested solar power systems but had not yet been installed. When those installations are completed, over 60% of rural Tuvalu households will have solar electric power.

Other resource constraints notwithstanding Tuvalu is endowed with an abundant year-round sunlight which, combined with the high cost of conventionally produced electricity at remote sites, makes it a model location for solar PV applications. However, an abundant solar resource and economic advantages are not sufficient conditions to cause successful PV based rural electrification. In the Tuvalu experience, eight years were required for the country’s solar programme to evolve to the point where PV systems functioned as customers expected and are technically capable of providing the required, reliable electrical service. It also took eight years to identify, test, and install reliable PV system components and to develop the required degree of technical, managerial and organisational expertise to make possible the success of the programme. Now with more than ten years of experience using photovoltaics, a number of important lessons have been learned in the design, operation and maintenance of PV systems and these were considered in the design of this rural electrification project.

*The Tuvalu Solar Electric Co-Operative Society*

Solar PV systems were first introduced in Tuvalu in 1979 to power the inter-island telecommunications system. In 1984, the Save the Children Federation (USA) began
planning a process for implementing solar electrification on outer islands of Tuvalu. The institutional design chosen was based on the recommendations of the Fiji Director of Energy who had the only prior experience in the region with a similar project. As a result of this effort, the Tuvalu Solar Electric Co-operative Society (TSECS) was formed in 1984 by the Save the Children Federation (USA) to provide small solar PV lighting kits to outer island households which at the time were illuminated exclusively by kerosene lamps. The TSECS has grown and generally prospered despite major technical flaws with systems provided by international donors. The organisational structure of the TSECS is both community and nationally oriented. Though receiving no government subsidy, the TSECS has access to external resources through the Tuvalu Government which has an agency to provide services to co-operatives. These arrangements provided the close relationships necessary for customer satisfaction even in the face of technical difficulty while remaining impersonal enough to collect fees and establish disconnect policies that were non-discriminatory.

PHASE 1 - SAVE THE CHILDREN (USA) ASSISTANCE

With the Save the Children Federation (USA) in the role of project co-ordinator, the TSECS was established as a private, commercial enterprise in April 1984 and charged with implementing and managing the household solar lighting project. The TSECS has no direct links with Government though it is regulated by government through the Co-operatives Act and must therefore submit annual reports for auditing. In May, 1984, using funding from the United States Agency for International Development (USAID), TSECS began operations with the purchase of 170 lighting kits. Their design was based on a combination of the recommendations of the Fiji Director of Energy and the Tuvalu Telecom Director. They were intended to provide basic household lighting of not more than 4 hours per night and consisted of the following components:

- 12V 35 Wp 30 cell Arco panel
- 12V modified car type lead acid battery
- 2 - 15 Watt Thinlite fluorescent fixtures.

Inclusion of discharge controllers was proposed by the Fiji Director of Energy but they were not included on the recommendation of the local Telecom Director who believed them to be unreliable and unnecessary. Units were initially installed on each of the eight islands on a pilot basis to familiarise the island community with the technology. Concurrently Save the Children Federation (USA) Island Development Co-ordinators were trained in system installation and maintenance. A TSECS Branch was established on each island when a minimum of 20 households deposited A$50 each with the TSECS and expressed their willingness to pay A$6.25 per month for the use of the household solar system. That financial arrangement was structured to cover maintenance over the lifetime of the system and component replacement costs for any part no longer operating to specifications as a result of normal use or accidental damage. It did not provide for recapitalization of panels, however. This was consistent with the Government pricing policy for Diesel generated power on Funafuti which also does not cover capital replacement.
The first Island Chapter of TSECS was established in 1984 and by late 1985 all 170 of the original lighting kits were installed. The systems worked poorly and most batteries failed before completing the first year of operation and often within six months of their installation. The primary reasons for early failure were (1) the 30 cell photovoltaic panel was inadequate to properly charge the battery, (2) excessive battery discharge was present in the absence of a discharge controller and (3) use of the lights was greater than anticipated by the system designers. Failure of lights were also common due to an apparent flaw in the electronic ballast.

In June 1988 after completing it initial objectives, Save the Children Federation (USA) withdrew its administrative support form the TSECS. The co-operative then became an independent, locally owned and operated commercial enterprise. While investment in PV systems has thus far been donor based, just as has been the Funafuti Diesel powered grid system, all TSECS operating and maintenance expenses have been paid by income from the member fees since 1988.

PHASE II: EARLY EU ASSISTANCE

The second phase of the programme began in 1985 and involved the installation of 150 household lighting kits provided by the EU (then EEC) under its Lomé II Pacific Regional Energy Programme (PREP). Those kits were modified from the initial design to include a battery controller to prevent abusive patterns of use. The new systems contained the following components:

- 42 Wp BP model 1235 PV Panel (some had 33 and some 34 cells)
- Fiji-made deep discharge type 12 V 90 Ah lead-acid battery
- Fiji designed and manufactured discharge controller
- D Cell NiCd battery charger
- DC/DC converter (series regulator type)
- 2 Thorn 2-D type 16 Watt fluorescent fixtures modified for 12 V DC operation.

The discharge controller was poorly specified by the donor with no mention in the specifications about internal energy use. The controllers provided were a first time design by a Fiji based electronics firm and their internal, continuous power requirement was over 2.5 Watts. Over a 24 hour period, the energy used by the controller equalled that used daily by one of the lights. As a result the system could not provide the amount of lighting needed.

The lack of a specification requiring a specific number of cells on the panel resulted in panels which were a mix of 33 and 34 cell units though the $W_p$ rating of all panels was as specified. At the high temperatures encountered by panels in Tuvalu, a 33 cell panel is marginal in its ability to fully charge a 12V lead acid battery when a daily use cycle is encountered due to the shifting of the maximum power point with increasing temperature.

The lack of an illumination efficiency specification in the tender resulted in the purchase of a light which consumed over 21 Watts of 12V DC power in a 16 Watt fixture. The
Light supplied was one which had been converted by the Fiji supplier from a 240 VAC fixture to 12V DC operation rather than a unit specifically designed for 12V DC PV applications.

The specifications did not require the supply of components which had a proven record of success in Pacific Islands PV service. As a result, the batteries chosen were of a new design, manufactured in Fiji, which had not been tested through field service in PV systems. Field experience and later laboratory tests showed that the quality control of the batteries was poor with some units performing as intended and others having a cycle life far less than that which was acceptable for PV service.

The inadequate purchasing specifications resulted in the supply of panels, controllers, batteries and lights which were technically inferior and when assembled as a system could not consistently provide more than two hours of lighting per night in Tuvalu. The results were again disappointing and did not meet users' expectations.

**PHASE III - FRENCH ASSISTANCE**

To overcome the component problems and design flaws of the initial PV systems funded by USAID, external grant assistance was secured from the French Government in 1987 to upgrade those systems by their provision of appropriate controllers and batteries. This emergency support kept the USAID systems operating and TSECS from an early failure though it did not solve the problems with the EU provided units.

Following its evaluation of the systems provided by the EU to Tonga and Tuvalu, the Energy Studies Unit of the University of the South Pacific (USP) determined that the design was technically inadequate. This was independently corroborated by the PEDP. As a result, the EU was requested to replace the unsatisfactory controllers and batteries as well as to add a second panel in the systems that they had provided under the 1985 scheme. The EU agreed and the equipment was ordered and provided in stages between 1988 and April 1990 under the Lomé II PV Upgrade Project for Tuvalu and Tonga. In this upgrade, the EU provided 160 Photowatt 36 cell panels including rack mounts and wire, 165 Oldham (France) 100 Ah 12 V deep discharge type batteries, and 175 charge-discharge controllers that were developed by the S.P.I.R.E. specifically for Pacific Island applications and assembled by GIE Soler in Tahiti, French Polynesia.

This upgrading project was completed in December 1991. As a final step to bring all systems up to an acceptable standard, an additional 125 12V 120 Ah BP Solar (Australia) batteries of comparable quality to the EU provided Oldham units were provided in 1992 through the FSED Small Energy Projects Programme. The purpose of this project was to replace those batteries originally provided in 1984 by USAID as well as many batteries from the French project of 1987 since a number of those batteries were only partially functional by 1992.

The period 1984-1991 was one of constant change due to problems with equipment and organisation. By 1992, the upgraded USAID, French and EU funded systems were providing satisfactory technical performance. Also a renewed emphasis by the TSECS on proper system use, increased institutional support, and improved service by the local technicians resulted in a higher level of customer satisfaction and few problems with
equipment failures and the TSECS was considered capable of handling a full project under the PV Follow-Up Project.

**Project Development Visit — 28 October to 5 November, 1991**

Two levels of involvement in the PV Follow-Up Project were proposed by the S.P.I.R.E. consultant: expansion of existing systems to increase their capability to handle additional entertainment appliances and a pilot project to determine the technical and social feasibility of much larger scale SHS through the provision of seven trial systems capable of providing urban scale electrical service including PV powered refrigeration.

At the time of the initial project visit, final negotiations had just been completed in Tuvalu for the provision of approximately 100 new SHS under the EU National Program of Lomé III. This project was integrated with the Lomé II PV Follow-Up Project with purchasing, training and external technical support made common to both projects.

The Tuvalu Government proposed the following concept and budget for the hardware component of the PV Follow-Up Project:

- **Priority 1**: To provide 60 two panel PV lighting systems for TSECS members not yet being served.
- **Priority 2**: To upgrade all 226 existing TSECS PV systems with one additional PV panel to improve battery life and system capability.
- **Priority 3**: To purchase and install eight trial PV systems for domestic photovoltaic refrigeration and lighting.

**Target Budget**

F$585,000

Because of the addition of the Lomé III project, the Tuvalu project remained the same size as proposed and the lower than expected component cost is reflected in the lower than budgeted expenditure.
• Siemens 50 Wp Panels F$215,660
• SEC Relay Type Controllers 39,496
• Oldham 12V 100 Ah lead-acid batteries 37,232
• Oldham 12V 425 Ah lead-acid batteries 16,289
• 11 Watt PL type Lights and spare tubes 2,714
• 7 Watt PL type Lights and spare tubes 5,427
• SEC Night Lights 5,595
• Domestic Refrigerators 17,829
• Switches, wiring and fasteners 23,266
• BP VR50 Vaccine Refrigerator systems (supplied without panels) 44,800

A. TOTAL EQUIPMENT F$408,308
B. INSTALLATION COSTS 26,000
C. TOTAL INSTALLED COSTS F$434,308
D. Tools and test equipment 11,984
E. Solarimeters 25,825

TOTAL FUNDS EXPENDED IN TUVALU F$472,117

Pre-Installation Consultancy Visit — 2-22 April, 1994

PROJECT CONTENT AND DESIGN

In the Pacific region, Tuvalu has the most experience with the use of photovoltaics for Rural Electrification and the Tuvalu Solar Electric Co-operative Society (TSECS) has been operating successfully and continuously as a rural electrification utility since 1984. Therefore the project for Tuvalu needed to be significantly different than for the other countries which are in the early stages of PV based rural electrification. One of the most important problems facing the TSECS is the desire by many of its users for service beyond basic lighting. Therefore one part of the project was to make available large systems for trial. These were capable of supplying sufficient electricity for a video system, refrigerator, lights and radio/cassette player. Seven such systems were provided which include a 12 VDC refrigerator, 435 Ah battery and sufficient panels to power the refrigerator, a video, lights and a radio/cassette player. The system can be provided to regular users at a monthly fee commensurate with the service capability, around A$40 to A$50 a month. The pilot installations were installed at the residence of the field technicians on each island for service trials and for demonstration to island residents.

Additionally, those users which had two panels were upgraded to three and users with one panel were upgraded to two. It is expected that battery life will be extended as much as 25% thereby reducing the monthly cost of the system sufficiently to offset the added cost of the extra panel over a 15 year system life. The three panel systems have sufficient capacity to operate lights and a radio/cassette player.
Also upgraded were the charge controllers remaining from early USAID and French projects and some batteries which had reached the end of their useful life.

Besides the domestic installations provided under the Lomé II project, seven PV vaccine refrigeration systems from BP Solar were provided for dispensaries. These are owned by the TSECS and a monthly fee of A$35 is charged to the Health Department for the maintenance service at each dispensary. These units replace the failed systems provided under an early project of the EU. The failure of the prior installations was the result of poor maintenance provided by the Health Department as well as technical problems caused by improper component selection for the systems.

In addition to the Lomé II Follow-Up Project upgrades, 100 two panel basic lighting systems were provided under the Lomé III National Programme of the EU. These are identical in design to the systems being installed in Tonga and Kiribati. In the actual installations, all components of the PREP and National projects were combined and no attempt was made to separate them by project type.

At the end of the installation period for the Lomé II PREP and National EU projects, approximately 385 domestic systems were in place with sizes ranging from two panels to eight panels. Additionally, seven dispensaries had PV powered vaccine refrigerators and basic lighting. The goal of replacement of all controllers, batteries and light fixtures which were of lower than acceptable quality was reached. At the conclusion of the work on the project by mid-1996, all systems will have a S.P.I.R.E. type of controller manufactured either by GIE Soler of Tahiti or the SEC in Kiribati, a high quality battery and high efficiency light fixtures of a proven design.

TRANSPORT ARRANGEMENTS

In Tuvalu the only means of commercial access to the outer islands is the Nivaga II, a small freighter which visits each island for a few hours approximately once per month on an irregular schedule. There are no airports on the outer islands. No charter boats are available in Tuvalu which can be hired at reasonable cost. The fisheries department boat, the Manaui, can be chartered but it is slow and expensive. Additionally the experience of the consultant on an earlier charter of the Manaui was not good, having been overcharged nearly 50%. Therefore the Manaui was not considered an acceptable option for visiting the outer islands. For these reasons, all consultancy work except for the final inspection was scheduled to take place on Funafuti. The transport for the final inspection was a 32 foot trimaran, the Martha, based in Kiribati.

BTA TRAINING AND PROVISIONAL ACCEPTANCE OF MATERIALS

At the time of arrival on Funafuti for the pre-installation consultancy visit, the panels, lights and vaccine refrigerator systems had been delivered to the TSECS. All controllers except for two cartons had also been delivered. The two cartons had been held up by customs due to irregularities in the air weigh bill and were to be released when clarification was provided by the originating shipping agent in Kiribati. The shipment of domestic refrigerators, cable, tools and batteries had arrived but had not been delivered from the wharf though it had been cleared for delivery. The shipment of hardware which had been purchased locally was on the wharf but had not been cleared.
The two containers with panels were opened and the panel cartons checked for damage. No damage was found and the panels in one container were partially unpacked and shifted to the other container in order to make room for the remaining container of materials. On Thursday of the first week of work, all components were delivered to the TSECS. On Friday, the container containing the shipment from Soler Energie (French Polynesia) was opened and checked. Minor damage was found on one domestic refrigerator due to one of the wire cable reels scraping loose a decorative cover plate. Two crates of battery acid were loaded on top of the battery crates but on their side even though they were clearly marked as to which side should be up. Some acid had leaked from the containers and had stained the wood crates but no damage to the batteries was found and the amount of acid lost was minor. During the second week, all light fixtures, electrical test equipment and electric tools were tested and found to all be properly operational. A number of 7 Watt lights were found to draw current beyond their rated value. These units have had a higher than acceptable rate of failure and the manufacturer has replaced all these units with new units having an improved design.

The technical consultant from S.P.I.R.E., Stéphane Pujol, arrived at the beginning of the third week of the consultancy visit. During that third week, controllers were tested and training of Branch Technical Agents (BTA) from the outer islands was begun by introducing them to controller testing and set point adjustment as well as the use of the electrical test equipment which had been provided. By the end of the third week all controllers had been tested. The locally purchased hardware had not been delivered by the end of the third week of the visit. Since access to those materials was necessary if the full training program was to be carried out, Mr. James Conway, the Energy Planner, assisted in expediting the customs clearance of those materials.

**RECEIVING Inspection Discrepancies Noted**

1) Solid instead of stranded conductor wire was provided. This was not a serious problem but results in added installation time due to the difficulty of arranging solid wire in the cramped space of the lights, panel and controller connection areas. However, solid wire is generally lower in cost than stranded wire of the same conductor size and it was recommended that compensation from the supplier be sought.

2) One seven Watt light was shipped without a bulb. The vendor provided the missing bulb.

3) Two light fixtures did not have the bulb clip installed. The vendor provided the missing clips.

4) No instruction manual was provided with the solarimeter. The manufacturer was contacted but had not prepared a manual for the instrument. A manual has been written by the consultant and was provided.

5) No instruction manual was provided with the Ampere Hour meter and name plates were in French. Since the materials provided by the
vendor were inadequate, a short manual was prepared by the consultant and was provided.

6) No instruction manual was provided with the portable adjustable DC power supply. This was later supplied by fax from the vendor.

7) One controller was found to be intermittently operational and was replaced by the manufacturer.

BTA TRAINING

The fourth week consisted of field training for the BTAs assisted by Stéphane Pujol from S.P.I.R.E.. The BTA training included short theory sessions delivered in English with translations where necessary followed by experiments which illustrated panel, controller and battery characteristics. The main training effort was focused around the installation of complete systems on two houses at the northern end of Funafuti where no power lines had yet been installed.

BTAs attending the training were Niti Malu (Vaitupu), Fawa Asotele (Namumea), Leuli Kokea (Nanumaga), Fagatoa Tito (Niutao), Boreham Maselusi (Niu), Talavalu Lipua (Nukufetau) and Sio Taumanu (Nukulaelae).

INSTITUTIONAL ISSUES

Immediately obvious to the consultant was the poor state of the management of the TSECS. A gradual degradation of management quality had been noted since the initiation of the project three years earlier and by 1994, conditions were very poor. Records were sparse and poorly stored, tools were rusty or lost. The computer was not operational and the room rented as an office was filthy and disorganised.

During the mid-project visit, the General Manager was generally not available to support the receiving inspections and training being carried out by the S.P.I.R.E. team, though no reasons for his absences were given. The Senior Technician was poorly informed about the shipments and was of little help in the training process.

As a result of the management discrepancies uncovered during the visit as well as the remarkable deterioration of the quality of the TSECS management support, the S.P.I.R.E. team investigated the accounts of the TSECS and found some serious irregularities. The Energy Adviser was informed and he followed up with an in-depth investigation which determined that the General Manager had been systematically embezzling large sums of money from the TSECS. Subsequently, the General Manager was suspended, tried in criminal court for misappropriation of funds, found guilty and sentenced to seven years in the Tuvalu prison.

Post-Installation Visit — 7 October to 17 October, 1994

HARDWARE PROJECT STATUS

At the time of this visit, about half the Lomé II installations had been completed. The delays in the installation progress were caused mainly by institutional problems resulting from the dismissal of the General Manager. For the period between the dismissal of the
former General Manager and the hiring of a replacement, the Government Energy Advisor, had been appointed as temporary manager and the position of General Manager was being advertised.

The time in Tuvalu was spent by the consultant primarily assisting the TSECS in its reorganisation through advice on institutional structure and management systems. A major problem of the TSECS structure had been the lack of oversight by either Government or a Funafuti based co-operative committee. The Board of Directors consisted of one person from each island which convened annually. The high cost of travel and subsistence associated with the Board Meetings made a more frequent meeting impractical and oversight by the board for day to day operations was impossible. It was recommended that a Funafuti based group be assembled which could act on behalf of the Board of Directors for countersigning checks and for other regular fiscal oversight.

After several meetings with Mr. Conway and the Chairman of the Board of Directors, who resided on Funafuti, it was proposed that a committee made up of members of the TSECS on Funafuti be appointed by the TSECS Board as a “business board” which would act on behalf of the Board of Directors regarding management decisions and other aspects of the business of the TSECS. The Board of Directors would retain responsibility for major decisions including hiring of management, setting of fees, membership arrangements and other issues relating to the structure of the co-operative.

Other institutional problems were discussed, including inadequacies in the communication of complaints from the field to the Funafuti office, the maintenance of discipline among the Branch Technical Agents and problems with record keeping, accounting and training. It was recommended that since Kiribati is in the process of instituting a filing and accounting system specifically designed by the consultant around the needs of a solar utility organisation, that the TSECS consider instituting the same computer based accounting system and a similar filing system.

Plans for the Forum Secretariat Small Islands States Fund financed office building were examined and minor changes recommended to improve functionality. The office was placed in service by December, 1995, greatly improving the working conditions of the Funafuti staff.

Project Inspection Visit (2 April-22 April, 1995)

A new General Manager was hired in late 1994. He immediately instituted major improvements in the management systems of the TSECS and by the end of the first quarter of 1995 had replaced the senior technician and hired a second, experienced solar technician for support of the BTAs.

The new components and those previously installed but still fully functional were freely intermixed throughout the systems installed on all nine islands of Tuvalu. In order to inspect the installation of the materials provided under this program, it was therefore necessary to inspect all systems installed in Tuvalu. This was done using the Kiribati based charter boat M.V. Martha over a three week period.

Due to the problems and confusion surrounding the dismissal, criminal trial and ultimate imprisonment of the former TSECS General Manager, at the time of the inspection visit the installations in Tuvalu had not been properly completed. All panels, controllers,
batteries and wires had been delivered to the sites and were connected electrically, but panel mountings had not been installed and wiring had not generally been completed to the standard required. The problem with the panel mounting was one of a lack of understanding on the part of the new management as to how the mountings needed to be made. A sufficient quantity of wood poles and planks were provided to Tuvalu for mounting panels but management believed that the materials were provided for other purposes and did not distribute those materials to the outer islands at the time of the shipment of the other system components. Therefore, the panels in almost all installations were simply laid on roofs and tied down with fishing line or cordage. Additionally, the senior technician responsible for directing the installation efforts of 1994 was shown in early 1995 to have performed his duties improperly and apparently even encouraged local technicians to bypass controllers and install systems in a manner known to be incorrect. Financial irregularities in his accounts came to the attention of management and he was dismissed. A new senior technician was hired shortly before the inspection visit.

Of further concern was the fact that despite the former manager’s statements to the contrary, most of the field technicians had never had formal training in the maintenance of the PV systems and it was clear from discussions with these technicians that they had little understanding of the systems and most of their knowledge had been gained through trial and error. Many misconceptions about the systems were noted on the part of the technicians and regrettably their primary mode of training was working with the former Senior Technician whose competency was later found to be questionable.

The result of this combination of confusion, mismanagement and incompetence was installations that work in the sense that lighting was being provided users, but were of such low installation quality that the long term prospects for attaining the expected battery life of five years were poor unless immediate action was taken to bring the installations to an acceptable standard.

It is a tribute to the viability of the institutional structure, the native intelligence of the local technicians and the quality of the systems being provided by the EU in recent years that despite its many management problems, the systems had in fact provided lighting service to the satisfaction of users and the purpose of the TSECS was being adequately fulfilled from the user’s point of view. Unfortunately, the long term picture was bleak since it was certain that unless installations were properly completed that batteries would fail prematurely and the cost of maintenance would far exceed the money received from users for that purpose. In the past, donors have provided replacement support, indeed the Lomé II regional project for Tuvalu includes many components for maintenance rather than capitalisation. Though donors may continue to assist the TSECS with capital investment for the extension or expansion of services, it is likely that they will insist that the projects be internally sustainable and that all operation and maintenance costs should be born by the users. From the point of view of the continued solvency of the TSECS, it was therefore imperative that the battery life reach or exceed the design condition of four to five years. For that to occur, installations had to be correctly completed and the field technicians properly trained to carry out their responsibilities to the users and the TSECS.

Fortunately, the TSECS had just installed a completely new and clearly more competent management in both the administrative and technical sense and since the new General Manager and the new Senior Technician accompanied the S.P.I.R.E. consultant on the
inspection tour, they received first hand knowledge of the problems. They were instructed in detail regarding the steps necessary to bring the installations to an acceptable standard and agreed to carry out the necessary work. As a preliminary step, the installation of the systems on Funafuti were properly completed and photographs have been provided to the consultant which show that proper installation methods were used and that the systems, if properly maintained, should deliver the long term service intended in their design. Technician training has been addressed and attendance by senior staff at overseas training sessions and local training of field technicians by those senior staff is planned. Assistance from the Lomé III PREP of the Forum Secretariat is being sought for training and assurances from the director of FSED have been provided that the training needs of the TSECS will be addressed in the Lomé III PREP program.

Though traumatic and serious, the personnel problems which have occurred resulted in a much strengthened organisation with a dynamic manager, competent technical staff and increased support and oversight from Government. This manifested itself not only in improved operations but in dramatically increased interest and participation on the part of the Management Committee and Island Committees which are the heart of the cooperative. A number of new management measures, including increased user fees to better insure sustainability and commensurate with the expanded systems, were approved by the committees. During the visit to most islands, the Island Committee heads participated in the inspection and agreed to actively take part in overseeing the maintenance operations by the field technicians.

The quality of performance of the field technicians (BTAs) was found to be very variable. Each technician had definite but different gaps in his training as shown by consistent but different errors in maintenance and installation procedures on each island. For example, the Nukufetau technician had bypassed most of the system controllers but electrical connections were properly made. While on other islands, controllers were properly installed but connections were often made by twisting two wires together.

The island which appeared to be receiving the worst technical support by the local technician was Vaitupu. That observation is consistent with the consultant’s findings in 1992 when the quality of maintenance on Vaitupu was also lower than any other island. Since the Vaitupu technician had been working in this position since the founding of the TSECS in 1984 it seems unlikely that his poor performance can be attributed to lack of experience or training. In 1992, the importance of wire sizing, good connections and the proper connection of controllers was explained in detail to this technician, yet in 1995 the same type of problems continued to be found in quantity on Vaitupu. It was therefore recommended that the Vaitupu BTA once again be carefully instructed in his duties and that the TSECS General Manager and the Government Energy Adviser make a surprise visit to Vaitupu three months or more after his instruction. If it was found that the quality of his work had not improved dramatically, then it was strongly recommended that he be replaced. On all other islands, technical problems could be attributed to a lack of support in the form of materials, spare parts and tools from the Funafuti office, to misinformation provided by the former Senior Technician during his visits or simply to inadequate training.

Unique to the Tuvalu installations was two cases of lightning damage. One involved one of the older vaccine refrigeration systems and resulted in the destruction of the charge
controller. The second instance was a strike which hit two individual home installations which are next to each other. That strike resulted in the destruction of both the controller and the batteries whose cases broke open but without significant damage to the house or injury to the occupants. While two strikes in eleven years does not indicate a serious problem, consideration should be given to determining the relative cost of panel frame earthing to the probable cost of future strikes.

Errors of Installation Encountered

Summary of the system inspections:

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<th>Inspection Item</th>
<th>% Excellent</th>
<th>% Good</th>
<th>% Average</th>
<th>Seriously Flawed</th>
<th>% Causing Probable Damage</th>
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<td>1.9%</td>
<td>4.3%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Wiring Connections</td>
<td>57.1%</td>
<td>0.5%</td>
<td>1.1%</td>
<td>0.5%</td>
<td>40.8%</td>
</tr>
<tr>
<td>Controller Mounting</td>
<td>98.6%</td>
<td>0.3%</td>
<td>0.0%</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Controller Location</td>
<td>96.1%</td>
<td>0.6%</td>
<td>1.1%</td>
<td>0.8%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Controller Condition</td>
<td>68.2%</td>
<td>0.0%</td>
<td>0.5%</td>
<td>1.1%</td>
<td>30.2%</td>
</tr>
<tr>
<td>Battery Mounting</td>
<td>98.6%</td>
<td>0.3%</td>
<td>0.0%</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Battery Location</td>
<td>99.5%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.3%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Battery Condition</td>
<td>97.0%</td>
<td>1.1%</td>
<td>0.0%</td>
<td>0.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td>Light Location</td>
<td>99.2%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.5%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Light Condition</td>
<td>88.5%</td>
<td>8.5%</td>
<td>1.4%</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

Nearly every installation included conditions which could cause premature system failure and had to be corrected immediately if battery life was to be acceptable. These conditions include:

Panels

Panels lying loose on roof without a mount.
Excessive shading
Serious mis-orientation
Wiring
   Wire not attached to building
   Interior wire used outside
   Wire too small for the length installed
   Wires twisted together for connection

Controllers
   Controllers hanging by wires
   Fuses bypassed with wires
   Controllers bypassed with wires

Batteries
   Exposed to the weather without protection
   Appliances connected directly to the battery
   Water level below the top of the plates

Lights
   Lights hanging by wires
   Lights extremely dirty
   High wattage bulbs inserted in lower wattage fixtures
   Lights mounted outside without weather protection

Conditions found which may have resulted in system damage and were a high priority for correction:

Panels
   Mis-orientation
   Shade
   Poor attachment to the building

Wiring
   Wiring poorly attached to building
   Crimped connections

Controllers
   No cover on the controller

Batteries
   Water below minimum level but plates not exposed
   No terminal covers or battery box
   Battery very dirty
Lights

Cover removed from electronic ballast

For details of the problems found and identification of which systems need correction, see the individual system inspection report provided in Appendix C.

Follow-Up Action

The condition of the systems at the time of the inspection was unacceptable. To fulfil the requirements of project completion, the TSECS agreed to properly complete all installations on all islands before the end of 1995. As of 1 October, 1995, all systems on Funafuti and about half of the outer island systems had been completely renovated to an acceptable installation standard and work was continuing on the other islands. By early 1996, all systems are expected to be installed properly and photographic evidence is expected to be provided the S.P.I.R.E. consultant who will notify FSED of the final condition of the systems at the end of the renovation project. It is recommended that a brief outer island visit be made by an FSED or S.P.I.R.E. technical staff person in the second half of 1996 to verify that the renovation has been properly carried out and that the BTAs have received the proper training and are providing proper maintenance.

The TSECS also has provided the consultant details of 1995 and 1996 training programs planned and completed which are intended to bring all technical staff to a satisfactory level of training. The first stage of training was the attendance of a TSECS contract technician, Mr. Kapuafe Lifuka at the AIT PV Refrigeration Training Course in June 1995. Since Mr. Lifuka has also received intermediate PV technical training at S.P.I.R.E. in 1986, he will be used as the primary local language trainer for field technicians as well as assuming primary responsibility for the technical support of the vaccine and domestic refrigeration systems in Tuvalu. The new Senior Technician who has no prior PV experience but has a strong technical background, has commenced self-study using manuals developed at S.P.I.R.E. and AIT and attended a basic course at CATD in 1995. The Tuvalu Energy Advisor, Mr. James Conway, has agreed to assist the TSECS in locating funding to complete their training.

Following the completion of the installations, the emphasis within the TSECS should be improvements in the efficiency of administration. Important to this effort are the completion of the integration of Quick Books accounting software as a computerised accounting system to allow faster response to changes in the TSECS financial status which will remain problematic for several more years and the implementation of a comprehensive monitoring scheme involving both field technicians and island committees to allow senior staff in Funafuti to judge the performance of field technicians and the operational status of systems without the need for numerous, expensive field visits.
COUNTRY COUNTERPART REPORT: Tuvalu

*Lomé II Photovoltaic Follow-Up Project*

*Final Country Report*

Prepared by the Tuvalu Energy Advisor, Mr. James Conway

**INTRODUCTION**

This paper provides a brief summary of the Tuvalu experience with the Lomé II Regional PV Follow-Up Programme. The paper also covers the work carried out through the Lomé III PV Programme which was funded under Tuvalu’s National Indicative Programme (NIP). The Lomé II and III programmes were a joint undertaking and were implemented simultaneously. Wherever the Lomé II programme is referenced, it also refers to the Lomé III programme.

The paper addresses the following issues: hardware and equipment, training goals and objectives, technical and administrative support, problem areas encountered, integration with other PV projects, and future (external) technical support requirements for the continued development of PV in Tuvalu.

**HARDWARE AND EQUIPMENT**

The PV systems supplied under the programme are providing excellent technical performance, in the event they have been properly installed and maintained. The hardware and equipment which was supplied offers an important evolutionary step in the development of household PV systems in Tuvalu. Nearly a year after installation, the systems are proving to be quite robust in terms of hours and quality of lighting service provided, material durability, and component reliability even if the systems have been poorly installed. Generally, this has resulted in a high level of customer satisfaction and minimal problems with equipment. However, there will be negative longer term consequences in terms of system performance and reliability if immediate corrective action is not taken to rehabilitate the systems that have been poorly installed or badly maintained. This work is now underway. Following the completion of the rehabilitation/corrective work — which is the result of the S.P.I.R.E. senior project consultant, Mr. Herbert Wade, in May 1995 — customer satisfaction is expected to further increase. Equipment performance and reliability will also improve, extending the life-cycle of the equipment to specification.

**TRAINING GOALS AND OBJECTIVES**

On balance, the goals and objectives of the training programme produced mixed results in Tuvalu. It is noted, however, that this is not the product of a fundamental weakness in the design or implementation of the programme, but rather it is the result of a high turnover rate of senior staff of the TSECS. This was the result of past mismanagement of the organisation which ultimately led to the formation of a completely new management team comprised of a manager, senior technician and nearly full time (local) technician on contract to the TSECS. The new management was in place as of April 1995. The contract technician was hired in May 1995.
Before proceeding further, it is worth noting that while the services and skills acquired by former staff under the Lomé II training schemes have been lost to the TSECS, these services and skills are not necessarily lost to the nation as long as the recipients of the training remain in country. It is possible that some of these employees, who departed for a number of reasons between 1992 and 1994, could return to the TSECS at some stage in the future and once again contribute to the development of solar PV in Tuvalu.

Thus far, the training received by the new staff — namely in the areas of materials testing, installation and completion testing — has been of high quality and has played a key role in the re-building of the TSECS. The month long inspection visit by the project consultant, Mr. Herbert Wade, proved invaluable in the above three areas as well as in providing instruction in the overall management of the TSECS. The high quality of work now being undertaken to rehabilitate a large number of installed systems is a direct result of the training and instruction provided by Mr. Wade during his final inspection tour.

As for the remainder of the TSECS staff, principally the field technicians on the outer islands, the training received was generally adequate. However, this was not always reflected in the quality of installation work carried out by the field technicians. Also, it is not necessarily a reflection of the quality of the field technicians themselves. In most instances, it is instead largely a reflection of the poor management oversight and lack of technical support from the TSECS head office in Funafuti for the period covered by the previous manager and administrators of the TSECS.

Due to the importance of reliable and skilled technical support in the field, it is recommended that future training programmes incorporate schemes that provide regular (e.g., annually) in-country refresher instruction which would maintain and strengthen the technical skills of existing staff and would provide essential training for new employees. This type of group training also has the often under-appreciated added value of encouraging an esprit de corps within the TSECS staff. Finally, in-country training of this type brings staff together who are otherwise rarely in contact for extended periods.

A major effort is to upgrade the technical competence and responsibility of the field technicians is seen as an important goal to ensure the long-term success of Tuvalu’s solar PV programmes.

TECHNICAL SUPPORT

The S.P.I.R.E. consultants, particularly Mr. Wade, provided extremely useful and appropriate technical support service to the project. Significantly, Mr. Wade was available on-call to assist the TSECS both during his in-country visits and at all other times during the course of the project. These efforts proved to be of invaluable assistance to the TSECS. When requests for advice were made, the responses were helpful and timely. It also is noted that the S.P.I.R.E. consultants interacted well with the local staff and are accorded considerable respect by them for their desire and willingness to assist the TSECS, their knowledge of solar PV development and PV project implementation, and their familiarity with and long term commitment to PV in general and the TSECS in particular.
Past experience suggests that higher levels of external technical support are required to ensure the long-term success of PV development programmes in Tuvalu. Over the years, Diesel electric utilities in all Pacific countries have received sustained and high levels of in-country technical support in all areas of operations, e.g. financial, administration, generation and distribution. Except in a few isolated examples, similar organisations providing solar PV to rural areas has not. As a new and evolving model for rural electrification, which has already demonstrated a potential for long term success, solar PV utilities such as the TSECS should be provided with levels of technical support that are similar in relative terms to those which have been and are being provided to island utilities generating with Diesel.

**ADMINISTRATIVE SUPPORT**

The administrative support provided by the Forum Secretariat Energy Division (FSED) and the EU was thorough and timely. Problem solving, requests for information, or other matters related to the project were usually handled promptly, either by phone or fax. Most notably, the efforts of Mr. John Vos, the EU Technical Advisor at FSED for the period 1991 through 1994 and those of Mr. Nick Wardrop, Renewables Advisor for FSED during the late 1994 through 1995 period are acknowledged and greatly appreciated.

**PROBLEM AREAS**

In the context of technical support, past experience suggests that the most useful training approach would be to have available an external technical advisor during the initial phase of installation work. In Tuvalu’s case, this would require an external technical advisor to be present, along with all the field technicians, during the installation of at least 15-20 PV systems and preferably for the completion of installations on one island. In Tuvalu, this approach is needed since most of the local technicians have had more actual field experience than the newly hired senior technician making them suspect the correctness of his advice particularly since that advice is often in conflict with that being provided by the previous senior technician. Therefore, an external advisor is needed to provide the outer island technicians with confidence in the training and advice being provided by the senior technician.

This approach would 1) strengthen the technical expertise and improve the general knowledge of project implementation of the management and technical staff at the home office on Funafuti; 2) improve the confidence and technical skills of the outer island technicians; and 3) impart to staff and local committees a better understanding of the activities necessary for the field technicians to provide the support services needed to insure customer satisfaction.

**INTEGRATION WITH OTHER PV PROJECTS**

The materials supplied under the projects integrated well with the existing PV hardware and equipment already installed in the country. Overall, in light of the past management problems with the TSECS, system the quality of service has met the expectations of the Tuvalu Government, the TSECS and the users. There are high expectations, by all parties, for the continued improvement in the quality and level of services provided by the TSECS, and the general system design as provided under the Lomé II and Lomé III projects is appropriate for future upgrading and system expansion.
FUTURE EXTERNAL TECHNICAL SUPPORT

The TSECS has been providing electricity service to the outer island households for eleven years. Recent experience has shown that solar PV for small rural loads can be competitive with other generation technologies. The quality of service provided by the equipment provided under this project and the service provided by the new TSECS management is greatly improved over earlier years. Nonetheless, the TSECS must continue to improve its systems and service as the demand for expanded electrical service is clearly on the rise on the outer islands.

To meet this demand, the TSECS will need to expand its technical and service capabilities through projects which are driven by user-demands for service which go beyond the lighting service traditionally provided by the TSECS.

About 200 unelectrified outer island households are currently awaiting the installation of solar lighting systems. Additionally a significant number of long-time members of the TSECS are awaiting the installation of hardware to expand their services to include appliances such as radios, stereos, videos and in some cases refrigerators. Carrying out the extension of service to new users and expanding the services of old users will have to be financed through the same process as grid extensions and power plant expansion on Funafuti — external donor funding to the TSECS through grants and soft loans.

For its part in the growth of PV based rural electrification in Tuvalu, the TSECS will need institutional strengthening in areas of existing technical and managerial weakness. It must increase service flexibility and become a more disciplined and professional organisation than it has been in the past. Some of these issues are already being addressed but most will require some form of sustained, though not necessarily continuous, external technical and managerial development assistance, such as has previously been provided to the Tuvalu Electricity Corporation almost continuously during its first twenty years of providing Diesel based electrification on Funafuti.