Evaluation of the PREP Component : PV Systems for Rural Electrification in Kiribati & Tuvalu (7 ACP RPR 175)

For the European Commission DGVIII Development

FINAL REPORT

Picture from the region (choose a photo)

March 1999

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Preface

An ex-post evaluation of the PREP PV follow-up project in Kiribati and Tuvalu was managed by ETSU in accordance with the procedures given in the Commission's Manual for Project Cycle Management, in four stages as follows:

1. Information gathering and validation
2. Mission to Fiji, Kiribati and Tuvalu
3. Review and Analysis
4. Conclusions and Recommendations

The information gathering stage began with a mission to Brussels on 30 July 1998 to collect documents and hold initial discussions with EC officials. This was followed by an initial review of the data and the making of contacts with individuals and organisations in preparation for the main mission to the region. The evaluation team attended a pre-mission briefing in Brussels on 23 September 1998, and then made an extended mission to the region in the period from 28 September to 6 November 1998. The mission included meetings in Fiji, Kiribati and Tuvalu with representatives of the Governments and regional organisations concerned, including the EC Delegation, the Forum Secretariat and SOPAC. Meetings were also held with the equipment suppliers and installers, including SEC and TSECS, and with the users in the outer islands of Kiribati (Nonouti, Marakei and N. Tarawa) and Tuvalu (Vaitupu, Nukufetau, and Funafala).

This report has been prepared in accordance with the specification given in the Terms of Reference for the evaluation, and attempts to address each of the issues listed there. Whilst this may have resulted in some repetition of the information presented, it has the merit that readers with different interests should be able to find the information which they are seeking with the minimum of effort.

Executive Summary

E1. Background

The EC has provided support to the Pacific Islands, including Kiribati and Tuvalu since 1984 through the Lomé II Pacific Regional Energy Programme PREP, which aimed to promote renewable energy and reduce dependence on imported fuels. Kiribati has 17 inhabited islands and a population of ~80,000, whilst Tuvalu has 8 inhabited islands and a population of ~10,000.

Following an evaluation of the PREP in 1988, the programme was redesigned and remaining funds were spent on new activities including a PV follow-up programme which was completed in 1995 at a cost of ~1.5 MEuro. This project included, inter alia, the installation of 250 PV lighting systems on the outer islands of Kiribati (Marakei, Nonouti, and North Tarawa), and 50 PV lighting systems, 7 larger (pilot) PV systems with domestic refrigerators, 8 vaccine refrigerators, and up-grading of 226 existing PV lighting systems in Tuvalu (together with a further 100 PV lighting systems funded under the Lomé III National programme)

E2. The Ex-Post Evaluation

The evaluation was specifically focused on Kiribati and Tuvalu. It studied the project's objectives, the approach used and the long term impact of the project. The technical, socio-economic, financial and institutional viability of PV technology were assessed, together with its sustainability in the outer islands. Two Logical Frameworks were constructed, one for the original objectives and a second to reflect current government objectives.

The Evaluation team visited the Region from 28 September to 6 November 1998, and held meetings in Fiji, Kiribati and Tuvalu with representatives of the Governments and Regional Organisations concerned, including the EC Delegation, the Forum Secretariat and SOPAC. Meetings were also held with the Solar Energy Company SEC in Kiribati, the Tuvalu Solar Electricity Co-operative Society TSECS, and users in the outer islands of Kiribati (Nonouti, Marakei and N Tarawa) and Tuvalu (Vaitupu, Nukufetau, and Funafala).

The visits to the outer islands and the discussions with officials were carried out together with representatives from the Energy Ministry in each Island State and the General Manager and technicians from SEC and TSECS. In this way, the local teams benefited from active participation in the evaluation process - "Participatory Rural Appraisal".

E3. Project Objectives

The data gathered and discussions held during this Evaluation showed that the original objectives of the Pacific Regional Energy Programme had been achieved, ie:

- to reduce dependence on fossil fuels
- to prove the suitability of PV technologies for the region

The PV follow-up project is also contributing to the current priorities of raising living standards on the outer islands, reducing migration to the main islands and creating sustainable jobs.

E4 Project Implementation

The project was well managed, and comprehensive project documentation is available. The government energy planners were closely involved in the project, and regional support was provided by the Forum Secretariat and more recently by SOPAC. The regional approach led to economies of scale in the purchasing of PV system components and shared costs of training.

E5 Results and Effectiveness

More than 95% of the PV systems in Kiribati were working well after ~5 years of operation, though the performance of >25% of the systems in Tuvalu appeared to be less than optimum. PV electricity has substituted approximately 1% of all annual petroleum fuel used or ~10% of that used in household sector, saving ~400 tons of CO_2 per year.

The PV modules, batteries and controllers in Kiribati were of good quality and almost all were operating well. Tuvalu has a mix of components, resulting from earlier programmes, and some batteries and lights were not operating properly, largely due to poor maintenance. Still, better lighting is improving the quality of life on the outer islands; and PV medical refrigerators are improving health care, though the reliability of the refrigerators was disappointing.

A total of 13 full time and 14 part time jobs have been created by SEC in Kiribati and 10 full time jobs by TSECS in Tuvalu. More than half of these jobs are based on the outer islands.

E6 Suitability of the PV technology and system sizing

The PV modules and batteries used were well suited to the local conditions, and the PV system controllers, which are made locally by SEC in Kiribati, were both resistant to the high humidity conditions and relatively easy to maintain and repair.

The system sizing (~ 100 Wp per household) meets the needs of the majority of users. The PV array is larger than would normally be sold directly to an individual user with only lighting and radio loads, but is well suited for systems which are owned by a PV Utility, where the lifetime of the battery is vital to the economic sustainability of the business. By slightly “over-sizing” the PV array, compared with common practice, the PV Utility can ensure that the battery is regularly overcharged, its electrolyte is well stirred and its life maximised. A slightly over-sized array also allows for some energy losses caused by ageing of the modules and battery, and for voltage drops arising from corrosion of cable connections. Nevertheless, regular cleaning and topping up of the batteries is vital to achieving the designed battery life of ~5 years.

E7 Socio-economic background

Typical households in the outer islands have 6-7 members and there is often more than one family unit per household. The men spend their time looking after their land and buildings, growing taro and copra (in Kiribati only) and fishing, whilst the women are typically responsible for child care, cooking, washing, cleaning, sewing and handicrafts. The GDP per capita in Kiribati is ~ 808 AUD (1991) and in Tuvalu it is ~1,480 AUD (1991). The difference in GDP per capita is thought to be mainly caused by the larger proportion of sea men in Tuvalu.

E8 Benefits arising from the PV project

The direct benefits of domestic PV lighting include convenience, improved safety and a better the quality of life in the long evenings - it gets dark at around 6 pm every night.

PV electricity brings a wide range of benefits to the island communities, including : fishermen use PV lights to prepare to go fishing and their wives use it to prepare the night fishing catch; pastors use it to read and prepare their sermons; medical assistants can work at night; vaccines are stored in PV refrigerators; schools can power personal computers and printers; children can listen to music; and families can use CB radios to communicate with distant relatives.

PV electricity is unlikely to lead directly to a significant amount of new income generating activities in the outer islands because of the extreme isolation, lack of access to markets, and limited resources from which to generate incomes, ie: fish, copra, leaves or shells for handicrafts.

E9 Impacts of the project

The main long term impacts of the PV follow-up project have been to provide good quality, convenient , safe and sustainable lighting for ~34% of the outer island households in Tuvalu and ~4% of outer island households in Kiribati, together with affordable access to radio and music.

E10 User satisfaction, willingness to pay, and future markets

All interviewees said they were satisfied with their PV lighting, and the field technicians in the outer islands have waiting lists for new systems. However, only 10-15 households on each island have paid the 50 AUD deposit, because the technicians will not take money from more families until new systems become available. Estimates of the remaining demand for PV systems from unelectrified households in the outer islands are >3500 in Kiribati and 400-600 in Tuvalu.

E11 Financial analysis

The PV Utility services (operation, maintenance and component replacement) run by SEC in Kiribati and TSECS in Tuvalu were found to be soundly based. The EC funding paid for most of the initial capital costs of the hardware, which represents ~50% of the system capital costs for the first 20 year life-cycle. The other half of the hardware costs and all of the operating and maintenance costs were paid by the users through an initial down payment of 50 AUD, followed by monthly fees of approximately 10 AUD per household (see Figure E1 below).

The PV Utility scheme, which was established by the PV follow-up project, has shown itself to be sustainable on a commercial basis for the long term with affordable monthly fees (~10 AUD).
Once installed, ***no further subsidies are needed***, provided that the fees are paid into an interest bearing Bank account where they will earn enough to cover the system capital costs during its life cycle, including the replacement of PV modules and refurbishment of the cabling after 20 years. (see Figure E2). Current estimates suggest that ~1000 systems are needed to cover the operating overheads of the PV Utility and to ensure long term sustainability of the service.

In Kiribati, the PV Utility service is working well and is ready for expansion. In contrast, the service in Tuvalu has suffered from poor management in recent years and is rapidly approaching a financial crisis. Poor maintenance in Tuvalu is already resulting in serious hardware failures, and urgent steps are needed to restructure TSECS in order to save it from collapse.

(Note: The option of selling PV systems to users and financing them privately or by soft loans was shown to fail in the Pacific in the earlier PREP projects and should not be repeated. The "PV sales to users" approach has also led to problems in other countries, because it encourages the purchase of cheap poor quality components and minimal maintenance, which lead to early failures and poor long term sustainability).

Figure E1 Capital costs of a PV system in a PV Utility scheme of 1000 systems over a 20 year life cycle

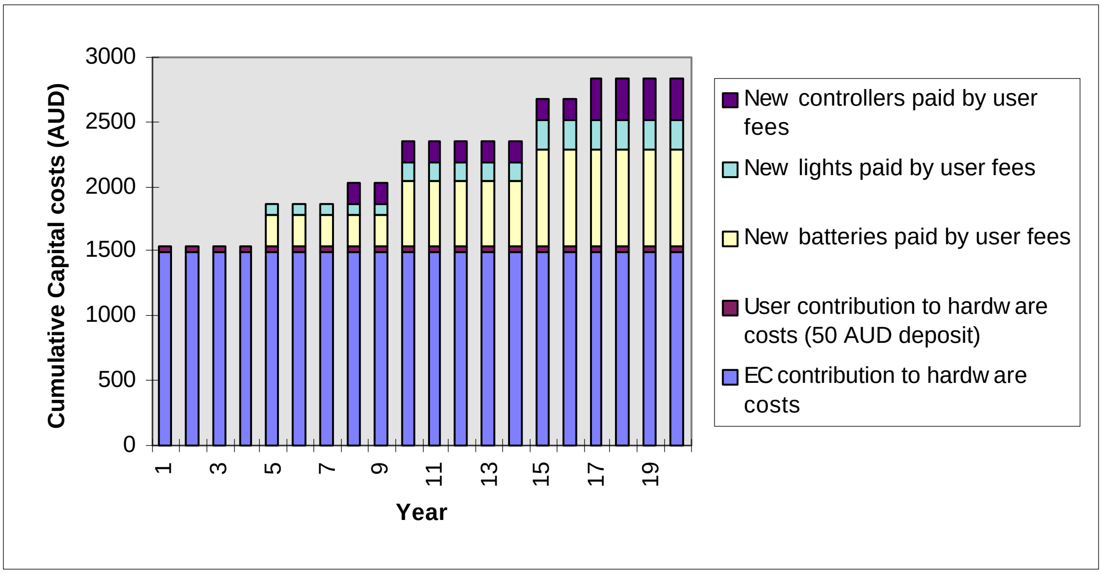
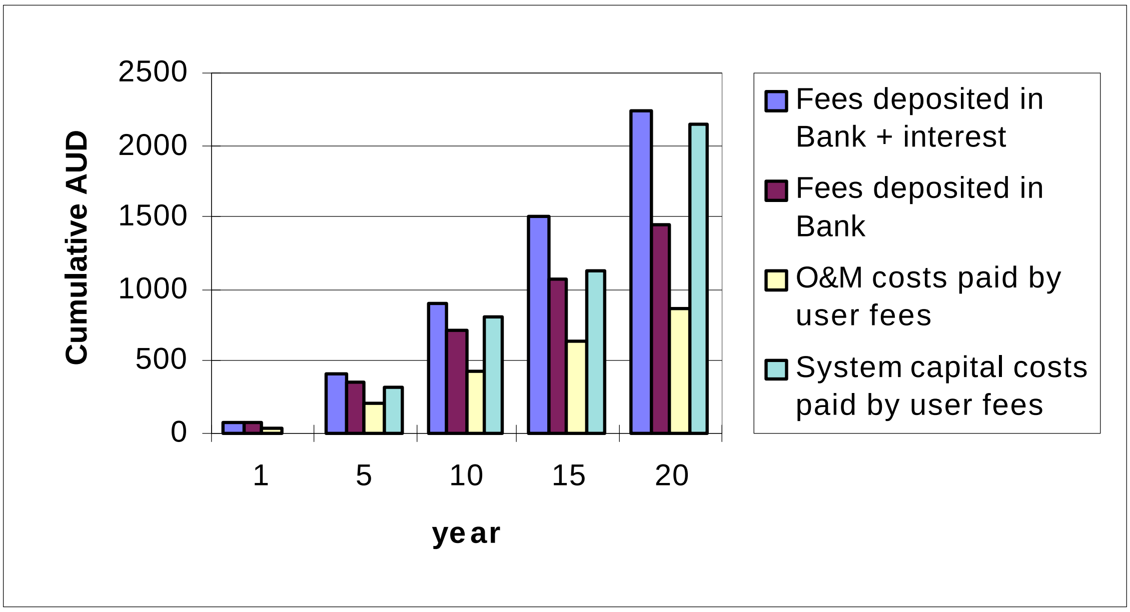


Figure E2 PV Utility fees and costs



E12 Affordability (ability to pay for PV systems)

The households interviewed during the evaluation confirmed that the range of household incomes is typically 150-300 AUD/month in both Kiribati and Tuvalu, though households with sea men may have higher incomes. They also confirmed that PV Utility fees of 10-12 AUD/month are acceptable, and are comparable with typical monthly tithes to the church. Nevertheless, strict enforcement of a disconnection policy is necessary to ensure that fees are collected, whilst keeping fees at a level which is affordable by the poorer households.

E13 Sustainability

The "PV Utility" service in both countries is based on the model which was first developed very successfully by TSECS in Tuvalu and later adapted by SEC for use in Kiribati. This scheme is both technically and economically sustainable in the outer islands, and is also the most cost effective when compared with the available alternatives.

The solar companies need on-going high level guidance and political support to ensure the long term sustainability of their PV Utility schemes. Political support can be given through government officials on the Board of Directors, and by practical measures such as reducing import duties on PV system components and promoting PV electrification for the outer islands.

The PV Utility of TSECS in Tuvalu is not sustainable, largely because of the institutional framework under which the co-operative society was originally established. TSECS is managed without direct Government support, and is under the control of a Management Committee whose members typically have little or no international business expertise. As a result, it has been poorly managed for several years, and poor maintenance is leading to increasingly serious hardware failures and a fast approaching financial crisis. This situation has been appreciated by the Government of Tuvalu, and the annual speech by the Governor General in June 1998 specifically referred to the importance of restructuring TSECS. Until TSECS has been restructured, it would make no (economic) sense to invest in new PV systems or in further PV training there. The most helpful step that any donor could take in the near future would be to work in partnership with the Government of Tuvalu to restructure the TSECS.

E14 Gender issues

Many of the benefits of the PV systems were found to apply to all members of the household, regardless of gender or age. However, women benefit particularly from lighting whilst preparing food, dealing with the night fishing catch and tending to sick children at night. Men benefit particularly from lighting when preparing to go fishing at night and when getting ready to go off to work on their land early in the morning (before dawn).

E15. Environmental issues

PV is environmentally better in the outer islands than diesel or petrol generators, because it produces no noise or emissions of fumes or greenhouse gases. PV systems produce almost no visual impact in the outer islands (it is often difficult to see them - even from a short distance).

The transport of liquid fuels to the outer islands carries high risks of leakage into water supplies and marine fisheries, and will remain a major problem for Kiribati and Tuvalu in the future. The practical difficulties of transporting fuel to the outer islands include transfers by small boat, and floating oil drums to shore before rolling them up the beach and placing them in open storage areas, where they heat up in the sun. Rapid corrosion and rusting is another problem.

A battery recycling scheme will be needed in the near future, since the PV system batteries must all be replaced during the next few years. Disposal schemes are also needed for dry cell batteries (used in portable torches) and for the growing number of plastics (particularly water bottles), tins and aluminium drinks cans that are being used in the outer islands.

E15 Recommendations

R1 Increase the number of PV systems in Kiribati

The Government of Kiribati should work with SEC to secure new donor financing to pay for 200 new PV systems per year over the next 5 years with a view to increasing the number of PV systems in Kiribati to more than 1000.

R2 Restructure TSECS as a government owned Corporation

As a matter of urgency, the Government of Tuvalu should build on the earlier successes of TSECS and restructure it as a separate government owned Corporation (similar to SEC) with a Board of Directors consisting of senior government officials and a representative from the Tuvalu Bank. Donor aid is needed to refurbish the existing PV systems and to train new staff. *(Note: The Energy Co-ordinating Committee is responsible for the restructuring of TSECS, with support from the energy advisers of SOPAC, and overall approval will be needed from the Cabinet. In order for the restructuring to be completed as quickly as possible, it is recommended that additional support for managing the process should be made available from the Special Services Unit in the Prime Minister's Office)*

R3 Do not privatise SEC in the near future

The Government of Kiribati should reconsider its proposal to move SEC into the private sector in the near future. There are no clear benefits from the privatisation of a monopoly, and it would not be commercially viable for another company to compete with SEC until the PV Utility market is about 10 times its existing size.

R4 Provide advanced training for PV Utility staff

Advanced training is needed to develop the skills of senior technicians in trouble shooting for the more complex problems which are now appearing in the older PV systems. This is a logical follow-up to the earlier training on installation practices and routine maintenance. Similarly, advanced training is needed to develop the business skills of PV Utility staff in stock control, international procurement, and business management. (*Note: This training would be of benefit to PV utility operations in several Pacific island states, and could therefore be shared with others in the region.)*

R5 Reduce import duties PV system components

The Government of Tuvalu should follow the example of Kiribati and reduce the import duty on PV modules from 30% to zero %. Similarly, the Government of Kiribati should follow the example of Tuvalu and reduce the import duty on cabling for PV systems from 50% to zero %.

The duty on deep discharge batteries for PV systems should be reduced from 30% to zero %. This would discourage the use of inappropriate car batteries and make sustainable designs more affordable. Similarly, the duty on energy efficient light bulbs should be reduced from 25% to zero %. This would not only reduce the costs of PV lighting, but would also encourage energy savings in the grid connected houses on the main islands.

R6 Install some larger "pilot" PV systems in Kiribati

A number of larger PV "Pilot" plants should be installed and monitored in Kiribati to build local experience. These should be large enough (say 400 - 500 Wp) to power a TV and video or domestic refrigerator in addition to household lighting. A key feature of the PV pilot projects should be a strong focus on the energy efficiency of the user appliances to which they supply power. Substantial international efforts have been made on Energy Labelling in recent years, and the projects should benefit from the published guidelines and Directives on this topic.

R7 Encourage more local manufacture of PV system controllers

Future projects in the region should encourage the production (and development as necessary) of the controllers which have been manufactured locally by SEC, with a view to expanding the potential for local job creation and exports.

R8 More PV lighting and power for computers in schools

Advantage should be taken of the experience which has been gained with PV systems in the secondary school on Nonouti, and more PV systems should be installed to enhance the education of children in both Kiribati and Tuvalu.

R9 Improve sales and distribution of PV light bulbs

The distribution of high efficiency light bulbs (eg: Philips PL) was found to be weak in Kiribati and in Tuvalu. Both SEC and TSECS should review the ways in which they are marketing replacement light bulbs and seek cheaper and more effective ways to ensure that their users can obtain light bulbs easily and at minimal cost.

R10 Establish a battery recycling scheme

A large number of lead acid batteries will need to be replaced during the next two years in both Kiribati and Tuvalu. The old batteries need to be removed from the outer islands and disposed of without causing environmental pollution. The respective governments should ensure that SEC and TSECS take responsibility for removing the old batteries and arranging for them to be recycled (possibly in Fiji). *(Note: There may be advantages in addressing this issue on a Regional basis)*

R11 Training / repairs / spare parts for medical refrigerators

Spare electronic and electrical components for medical refrigerators should be stored locally in accordance with World Health Organisation guidelines, and more training given on how to repair the refrigerators locally. Also, each new member of medical staff appointed to work in an outer island health centre should be briefed by SEC or TSECS on how to use the PV medical refrigerator and PV lighting system. Users' manuals should be provided in the health clinics.

Glossary

ACP	Africa, Caribbean, Pacific
Ah	Ampere hours
AUD	Australian dollars (1 AUD ≃ 0.6 Euro)
AVO	Amperes, Volts and Ohms (meter)
BTG	Name of Dutch consulting company
CB	Citizens' band (radio)
EC	European Commission
EU	European Union
FSP	Foundation for the Peoples of the South Pacific
GDP	Gross domestic product
GTZ	Name of German Agency / consulting organisation
JICA	Japanese International Aid Agency
kl	kilo litres
kW	kilowatts
kWp	kilowatts peak - power rating of PV modules in standard test conditions
LED	Light emitting diode
Lomé	European funding agreement for ACP States
MEuro	million European currency units (equivalent to the old ECU)
MOU	Memorandum of Understanding
NiCd	Nickel Cadmium (batteries)
O&M	Operating and Maintenance
PIS	Pacific Island States
PNG	Papua New Guinea
PREP	Pacific Region Energy Programme
PV	Solar Photovoltaics
RE	Renewable Energy
RERF	Revenue Equalisation Reserve Fund (Kiribati)
SCF	Save the Children Fund (from the USA)
SEC	Solar Energy Company (based in Kiribati)
SPC	South Pacific Commission
SPIRE	South Pacific Institute for Renewable Energy
TCS	Tuvalu Co-operative Society
TSECS	Tuvalu Solar Electricity Co-operative Society
TV	Television
UNCDF	United Nations Capital Development Fund.
USAID	United States Agency for International Development
V_{oc}	Open circuit voltage
Wh	Watt hours

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1. Introduction

1.1 GENERAL BACKGROUND

The European Commission has provided support to the Pacific Island States, including Kiribati and Tuvalu, since the early 1984, in the framework of the Lomé II Pacific Regional Energy Programme PREP, for which a Finance Agreement for 6.19 MEuro was signed in June 1984. The PREP aimed to promote the use of indigenous and renewable sources of energy and to reduce dependence on imported fuels. An overview of the key activities associated with this programme is given in the form of a "Time-Line" Table in Appendix 4

The programme's original 22 hardware projects were designed as pilot and demonstration projects to ascertain the advantages and disadvantages of each technology in the Pacific region. As many as 11 of the initial projects were cancelled for a variety of reasons. The technologies evaluated in the remaining projects include wood and charcoal gasification, utilisation of coconut oil as motor fuel, domestic and institutional wood stoves, charcoal production, solar photovoltaics (for domestic lighting, medical refrigerators and telecommunications), solar water heating, micro hydro power assessment (hydrological surveys). Power demand analysers and training were also provided.

After the programme evaluation at the 1989 Regional Energy Meeting, the following new projects were proposed, which placed more emphasis on energy conservation, manpower development and training:

- Kiribati energy conservation project (largely completed in 1993 - this project also included the installation of PV powered telephone systems)
- Western Samoa energy conservation project (largely completed in 1993)
- Biomass Follow-up programme (proposals made for 4 projects, but not approved by EC)
- Photovoltaics PV follow-up programme (completed in 1995)

The PV follow-up project was implemented by the Forum Secretariat's Energy Division, based in Fiji, and was funded initially under the EC Lomé II Pacific Regional Energy Programme (PREP) and later under Lomé III. It was initially estimated to cost 1.5 MEuro, and was designed to train personnel in the identification, planning and implementation of PV projects and to supply hardware to Fiji, Kiribati, Papua New Guinea, Tonga and Tuvalu.

The following projects were designed under the PV follow-up project in late 1991 by the participating countries with Technical Assistance from BTG and the project consultant SPIRE:

- Kiribati - 250 PV lighting systems for Marakei, Nonouti, and North Tarawa
- Tuvalu - 50 PV lighting systems, 7 larger (pilot) PV systems with domestic refrigerators, 8 vaccine refrigerators, up-grading of 226 existing PV lighting systems (project was integrated with a further 100 PV lighting systems funded under the Lomé III national programme)
- Fiji - Rehabilitation of 68 lighting systems at Namara Village, Kadavu
- Tonga - 50 PV lighting systems
- PNG - PV training and demonstration facility at the new Energy Dept offices

An important element of the PV follow-up project was a series of workshops and training for the solar companies and co-operatives in the participating countries on the preparation of Tender documents, Tendering, and the evaluation of Tenders. These provided significant institutional strengthening and helped SEC to develop the skills necessary for the local manufacture of electronic controllers and converters. An international call for tenders was launched in November 1992 for companies to supply the hardware needed for these projects, and this was largely delivered during 1993 and 1994.

The equipment was delivered ready for installation to SEC in Kiribati and to TSECS in Tuvalu, where it was inspected, tested and provisionally accepted. The suppliers were paid on the basis of equipment acceptance documents, and the local companies SEC and TSECS were contracted by the Forum Secretariat to install the systems and train the staff and users, with technical assistance from the project consultant SPIRE (Herbert Wade). SEC and TSECS were pre-selected as the installers of the PV systems, following the training activities described above.

Following the installation and training, a complete inspection of all systems was carried out by the project teams, led by the project consultant, SPIRE. Details of the findings of the inspection mission are contained in the Final Report on the PV follow-up project, which was published in 1995. This report shows the results of inspections on all of the systems that had been installed, and specific matters were identified which needed to be corrected in many of the systems (e.g.: PV modules not adequately fastened to roof, fuse by-passed, or control sensor removed). Relatively few serious problems were identified in Kiribati but, owing to the weak management and high staff turnover in TSECS, there were far more problems in Tuvalu, although some of the errors but by no means all were eventually corrected.

Following completion of the PV follow-up project, the EC provided funding for a regional training and capacity building project under Lomé III through the PREP. This was focused on the power sector, but also covered PV and was managed by GTZ / BTG. While this project was being implemented, it was proposed that an Ex-post Evaluation of the PV follow-up project should be carried out, specifically focused on Kiribati and Tuvalu. The report presented here is the result of this Ex-post Evaluation.

During the course of the original PV follow-up project and since its completion, a vast quantity of literature has been produced on the work done. Some of this literature has been complimentary, some critical and some explanatory. It would not be appropriate to include detailed comments on each of the documents here. However, much if not all of the available literature has been reviewed during the course of this evaluation and the information gathered has been integrated into our findings. A list of the documents which have been collected is presented in Appendix 2.

1.2 OBJECTIVES AND WORKPLAN FOR THE EVALUATION

The objectives for this ex-post evaluation were as follows:

1. To assess the coherence of the programme's objectives with the objectives of the concerned Governments and the adequacy of the approach used by this programme in the specific field of PV;
2. to draw elements of appreciation, in order to assess the technical, socio-economic, financial and institutional soundness of the use of PV technology in this region, particularly in regard to its socio-economic and technical sustainability,
3. to formulate recommendations in order to give guidance for the possible further use of this technology in this region and concerning elements of possible replicability.

The evaluation was carried out in four stages as follows:

1. Information gathering and validation
2. Mission to Fiji, Kiribati and Tuvalu
3. Review and analysis
4. Conclusions and recommendations

The work plan for the evaluation is illustrated in Figure 1

Figure 1.1 Project Workplan

Activity	Month

	1998 Aug	1998 Sep	1998 Oct	1998 Nov	1998 Dec	1999 Jan	1999 Feb	1999 Mar
1. **Information gathering and validation**								
2. **Mission (Fiji / Kiribati / Tuvalu)**		*Mission*						
3. **Review and analyses**								
4. **Conclusions & recommendations**								
5. **Management and Reporting**								
Mission planning and organisation								
Inception report		●						
Draft Final Report					●			
Receive comments from EC								
Final Report								●
Meetings with EC in Brussels	■	■						■

1.3 INFORMATION GATHERING AND VALIDATION

The first task in the evaluation was to gather as much as possible of the relevant information on the background to the projects, their context and relevance, implementation, results, impacts and sustainability. This work involved an initial visit to Brussels, when discussions were held with the following EC staff:

- Mrs Susanne Wille — general evaluation and project management issues
- Mr Ernst Kroener — regional issues
- Mrs Myfanwy Van de Velde — issues related to Tuvalu
- Mr Carl Henrik Hall — issues related to Kiribati
- Mr Henri Martin — technical information on PV in Pacific region
- Mr Howard Barton — history of the project and technical issues

A large amount of documentation on the project was provided by the EC in Brussels, and subsequently by the EC Delegation (Mr Claus Kondrup) in Fiji. Further documentation was obtained from the SEC in Kiribati and the Ministry of Works, Energy and Communications in Tuvalu. A list of the main documents used in this evaluation is given in Appendix 2.

As there was no original ***logical framework*** for this project; one had to be built in order to examine the context of this evaluation (see Appendix 3). This framework contains the original objectives of the project, the indicators that can be used to measure the extent to which these objectives have been achieved, and the sources of information that can be used to determine these indicators. It also contains the expected results of the project and details of the activities that were expected to occur during the project. Taking into account what actually took place during the project, and the more recent priorities of the governments concerned, a second logical framework (also presented in Appendix 3) has been built as an example of what might be used for future remote island PV electrification projects.

A draft checklist ***questionnaire*** was prepared to assist in the gathering of information during the mission (see Appendix 5). The questions given in this questionnaire were used as a checklist during discussions with the various organisations and individuals met during the mission. (Initially, it was envisaged that a series of targeted questionnaires might be used, but on finding that the knowledge and involvement of many individuals span several aspects of the project, it was decided to use only one questionnaire on a checklist basis.). During the mission to the region, information was also gathered on the relevant aspects of similar ***PV projects funded by other donors*** in the region.

1.4 MISSION TO FIJI, KIRIBATI AND TUVALU

The mission to the Pacific region was carried out from 29 September to 6 November 1998, by Dr Bill Gillett and Ms Gill Wilkins. A detailed Mission Log, showing the time spent in each country and the key meetings held, is presented in Appendix 6.

The mission included 13 days in Kiribati, during which 4 days were spent in Nonouti, 4 days in Marakei, 1 day in North Tarawa, and 4 in South Tarawa.

It also included 11 days in Tuvalu, during which 1 day was spent in Vaitupu, 1 day in Nukufetau, 1 day in Funafala, and 8 days in Funafuti.

In both Kiribati and Tuvalu, the visit was hosted by the solar company and the Ministry of Energy. We met with the staff of the solar companies, government officials, and PV system users. We also held meetings with other key organisations in the energy sector, and with those responsible for development in the outer islands.

Before going out to Kiribati and Tuvalu, 3 days were spent in Fiji to meet with the EC delegation, the Forum Secretariat, SOPAC and other donors who are active in the region. Similarly, 5 days were spent in Fiji on the way back from the islands, to report back to the EC delegation, the Forum Secretariat, and other interested parties.

2. Context and relevance

2.1 NATURE OF THE SOUTH PACIFIC ISLAND STATES

The South Pacific Island states of Kiribati and Tuvalu are groups of islands or atolls scattered over a vast area of ocean (see Appendix 13 for photos taken during the evaluation mission, and Appendix 14 for maps showing the geographical locations of the islands). Their isolation, lack of natural resources, and small market potential are significant barriers to economic development, and both are therefore the recipients of considerable quantities of aid funding. In particular, they are almost totally dependent for their energy needs on imports of petroleum products, and the EC funded PREP was specifically aimed at reducing this dependence.

Population increases and migration from the outer islands to the main island in each country is causing problems with clean water, sanitation and waste disposal. Population increases are being addressed by better education and action regarding family planning options. One way to slow down the migration of people to the main island, or to encourage retired people to return to their home islands is to provide better living conditions on the outer islands. For example household lighting, CB radio, telecommunications, radio/cassette, Video/TV, medical centres with vaccine refrigerators and electric lighting. PV systems can provide power for all these amenities.

Transport between the islands in each country is infrequent and expensive to run. The government of each country subsidises the costs of transport to the outer islands so that its people can travel to visit relatives, access schools and receive deliveries of goods at the same price as the main island. The infrequent, unreliable and costly nature of transport to the outer islands makes it desirable that electricity supplies on the outer islands should be independent of liquid fuel deliveries, require low levels of specialist technical maintenance and need relatively few spare parts. With respect to these transport problems, PV systems are well suited for use in the outer islands.

2.2 KIRIBATI

Kiribati, formerly the Gilbert Islands, is an independent republic which remains within the British Commonwealth. It is made up of 33 islands of which 17 are inhabited, with a total population of around 80,000. Its GDP per capita in 1996 was around 870 AUD, and its average electricity consumption per capita was less than 0.4 kWh per day (1993).

The government takes a cautious approach to public expenditure, and a supportive stance concerning the populations in the outer islands.

The Kiribati Revenue Equalisation Reserve Fund (RERF) provides the government with a sustainable long term source of income which can be used to support the basic development needs of the communities living on the outer islands.

We estimate that typical ***households on the outer islands*** comprise 6-7 persons and have incomes in the range 150 - 300 AUD/month. Families with seamen have higher incomes and some families have lower incomes than this, so the variations are quite large. Nevertheless, these values are broadly consistent with the Government statistics, which show an average GDP per household of approx. 360 AUD/month for all households (including those on the main island, South Tarawa). By comparison, the ratio of outer island income to national average income in Tuvalu is ~60%. If this ratio were applicable also to Kiribati, then the income per household in the outer islands of Kiribati would be 216 AUD/month.

2.2.1 Problems and actors identified in Kiribati

Problems

The key problem for Kiribati is its remoteness, which makes transport very expensive and communications difficult. It also suffers from extended periods of drought, which exacerbate the problems associated with clean water supplies and sanitation. Rain is so infrequent that the population relies on ground water supplies from small wells, which may have been adequate some years ago, but are now increasingly being polluted by nearby latrines. There is little, if any, sewerage infrastructure in the outer islands, and only a rudimentary sewage collection network in South Tarawa.

Communications with the outer islands are largely by CB radio (solar powered), though telephones have now been installed in the post offices of some islands (eg Marakei).

Transport of goods and personnel is normally by ship to all islands, but is also possible by plane in the case of Nonouti and Marakei. North Tarawa is accessible by small boat or by truck at low tide. Transport on the islands is possible by truck (each of the inhabited islands has one or more trucks) and motor cycle, but more commonly by bicycle.

Kiribati experiences high temperatures and all parts of the narrow atolls are very close to the ocean, so the air is typically very humid and carries a saline spray. This causes rapid corrosion of all metallic objects and system components. Electronic equipment and computers suffer not only from the high humidity and temperature but also from airborne fungi, which can quickly destroy floppy disks.

Key actors in the PV sector

The PV sector involves the following key organisations in Kiribati:

Solar Energy Company (SEC): The SEC was initially set up in the early 1980's and is still the only PV company in Kiribati. The Board of Directors of SEC includes nominees / representatives from the Ministry of Works and Energy (Chairman), the Kiribati Bank, The Ministry of Environment and Social Development, the Ministry of Finance, and the Ministry of Home Affairs. For further details see Appendix 10.

Ministry of Works and Energy : The Ministry of Works and Energy has responsibility for energy planning in Kiribati. Mr Mautaake, an Assistant Project Engineer from this Ministry, participated in the evaluation mission to the outer islands.

Ministry of Commerce, Industry and Tourism: This Ministry is responsible for setting the price of liquid fuels, through Prices Regulation Orders.

Ministry of Finance : This Ministry is responsible for National Planning and is involved in projects benefiting from international aid.

The Public Utilities Board : This is the Government Corporation that is responsible for the electricity grid and sewerage of South Tarawa. However, it is not directly involved with the supply or operation of PV electricity systems.

UNCDF : This UN agency is directly involved in projects to install PV powered water pumping in the secondary schools of Kiribati. SEC acts as a contractor for the procurement and installation of the PV elements of these systems.

Island Councils: Each of the outer islands of Kiribati has an Island Council, staffed by one or more full time civil servants, who manage the civic business of the island. They have a key role in the development of their communities, and provide important official links with the Government.

Ministry of Health : This Ministry is responsible for health centres on each of the islands and employs SEC to maintain the PV lighting and vaccine refrigerators in these centres under its PV Utility scheme.

KOIL : The Kiribati oil company distributes liquid fuels on the main island and in the outer islands.

KIRIGAS : The Kiribati gas company distributes LPG.

2.2.2 Beneficiaries of the PREP PV follow-up project in Kiribati

The EC funded programme has provided 75 solar lighting systems for individual families in each of the two outer islands of Nonouti and Marakei and 100 systems in North Tarawa. Each family had to pay a deposit of 50 AUD to demonstrate its willingness to pay for its PV lighting and has to pay a monthly fee of 9 AUD for the basic lighting system with 3 lights or 10 AUD if they also have a dc/dc converter to power a radio. Other than the requirement for a deposit, the systems were made available on a first come - first served basis, and there are still long lists of people waiting for a PV system.

No community PV systems were supplied under the EC programme, though the presence of the EC project has allowed the Solar Energy Company to become well established and to begin to offer PV services to other organisations, such as schools, medical centres and private individuals. SEC has a contract with the Ministry of Health to maintain the PV systems in the health centres of the outer islands.

2.2.3 Energy needs of the rural populations in Kiribati

The energy needs of the rural populations in the outer islands of Kiribati are still relatively low, the main requirements being for lighting, radios and cooking. However, there is a growing demand for videos and a demand for television can be expected within a few years, if TV signals are broadcast to the region in the future.

Some of the shops have already begun to install refrigerators and freezers powered by their own small diesel or petrol generators, so there could well be a demand for domestic refrigeration and freezers in the future. However, at the present time, there is little need for refrigeration since most of the food is in the form of freshly caught fish, rice and freshly prepared local vegetables. Fresh meat is available for special occasions from chicken and pigs kept by individual families. Any left over food is distributed to family and neighbours or fed to the pigs, chickens and other animals. The consumption of tinned foods is also increasing.

In recent years, there has been a growth in the demand for transport fuels, largely for motor cycles and a small number of outboard motors. This demand is significant when considered in terms of the need to supply sufficient drums of fuel each month from the main island, but it is unlikely to increase dramatically in the near future.

2.2.4 Use of energy in Kiribati

Cooking on the outer islands is mainly by burning coconut husks, though kerosene is used by less poor families, especially when it is raining. LPG is also used for cooking on South Tarawa, but not yet to any significant extent on the outer islands. Non solar lighting on the outer islands is by kerosene pressure lamps or lanterns. We estimate that the household expenditure on energy in the outer islands is typically 10-20 AUD/month (excluding the few households that have motor cycles or outboard motors).

The households with solar power typically have up to 3 lights and about half of them also have a radio. They use their lights from sunset (approx. 18:30) until they go to bed (typically between 22:00 and midnight), and then as required for any activities during the night such as dealing with a sick child, preparing to go fishing at night, or preparing fish brought back from night fishing. Some also use the lights in the early morning when they are getting ready to go to work. Work is typically done early in the day before it gets too hot.

2.2.5 The energy situation in Kiribati

There is a Public Utility Board (PUB) electricity grid on South Tarawa and a recent extension to the grid has been built to Nabiena. This stretches onto part of North Tarawa, but otherwise the only energy supplies to the outer islands are via the Kiribati Oil Company (KOIL). Energy prices are held constant on all islands because the government reimburses transport costs of goods to the outer islands in order to make it attractive for residents to remain there. These costs are met by an import levy on all goods imported into Kiribati, which is based on the volume of the goods transported (10 AUD/m^3).

Details of the oil and gas prices in Kiribati are summarised in Appendix 12, together with some historical data on overall energy consumption.

The real costs of fuel on the outer islands are very high, largely because of the costs of transporting the fuel, first to the main island and then onwards to the outer islands. Liquid fuels are transported in 200 litre drums to the outer islands by ship, and the drums are then transferred by small boat to the beach or floated to the shore, from where they are rolled up the beach to a holding compound - but not without problems. Most drums can only withstand a few trips over the coral reefs and up the beach before they begin to leak. Similarly, they cannot resist being left repeatedly to heat up in the midday sun without leakage. Because of the problems of leakage, drums of fuel cannot be stored in the same part of the supply ships as food and other goods, so the ship owners have to limit the number of drums carried on each trip. The ship owners are also somewhat reluctant to transport empty drums on the return trips to the mainland. As a result, there is a continuing shortage of drums, and a frequent shortage of liquid fuels on the outer islands. This situation is unlikely to change in the near future, since the size of the market for liquid fuels on the outer islands is likely to remain very small, and therefore there is little incentive for investment in better fuel transportation or distribution infra-structure.

2.2.6 Coherence of project objectives vs Kiribati government objectives

The objectives of the original PREP project - to reduce dependency on fossil fuels and establish the suitability of renewable energy technologies for the region - were in line with those of the Kiribati Government at the time, and were broadly maintained for the PV follow-up project. However, some more specific objectives of the Kiribati government have also been addressed by the PV follow-up project, notably rural electrification with the aim of improving the quality of life and enhancing development on the outer islands and so reducing migration to the main island (see section 2.4).

The Public Utilities Board is required to supply power to South Tarawa, but has no mandate to supply power to the outer islands. The provision of power to the outer islands is clearly seen by the Government as the job of SEC, which is fully coherent with the approach adopted in the PV follow-up project.

The PV follow-up project has helped to establish SEC as a viable government owned corporation, which has created employment both in South Tarawa and in the outer islands. Employment creation is one of the main objectives in the latest "Medium Term Strategy" published by the Government of Kiribati (November 1997).

The Medium Term Strategy of the Government of Kiribati in the energy sector emphasises the need for greater utilisation of renewable energy systems which are proven to be technically and economically viable, and suggests that the private sector should be allowed to take over the operations of SEC. However, the studies recently carried out by SOPAC together with the information gathered during the evaluation of the PV follow-up project suggests that it would not necessarily be in the public interest to transfer SEC to the private sector at this time. The key reasons for this conclusion are that :

a) the existing market for PV rural utility services is still very small, and therefore it is unlikely that any real competition could be introduced into this market. The privatisation of a monopoly is not generally considered to be wise.

b) the scale of the PV rural utility operated by SEC at the present time is too small to be economically sustainable. It is estimated that at least 1000 PV systems are needed to achieve a sustainable long-term business, and it is unlikely that more than one private enterprise could achieve this level of critical mass in the near future. In contrast, there is a far greater chance that if SEC were to remain as a Government owned Corporation, then it might attract the necessary aid funding to achieve the scale of activity required to achieve long term sustainability.

c) rural electrification, even in developed countries in Western Europe, is not a profitable business and generally has to be subsidised in one way or another. Typically, this is done either within a large National or Regional Utility by cross subsidies from the more profitable urban sales of electricity, or by a transparent levy scheme, such as the Facé scheme used in metropolitan France. The administrative burden on the Government of managing a free market subsidy scheme, together with some form of market regulation, would not appear to be justified at this stage for such a small and innovative market. It is likely to be far less costly to manage the development of the required rural utility services through a single government owned corporation.

2.2.7 Relevance to Kiribati of the Regional approach

At the time of implementing the PREP PV follow-up project, there was not sufficient local expertise in Kiribati to manage a project on this scale, so external assistance was essential. Economies of scale were obtained by employing this assistance for the benefit of several Island States at the same time, especially for the work involving training and the development of local skills. Similarly, economies were achieved by tendering for the bulk purchase of standard items, such as PV modules, batteries and cabling.

The PV follow-up project benefited from the involvement of the Forum Secretariat, whose Energy Division provided technical and management expertise on a Regional basis. This expertise has now been transferred to SOPAC, who still provide a valuable service in bringing together the experiences of the different Pacific Island States, and facilitate the cross-fertilisation of ideas though regular meetings and exchanges of personnel. When considering the future funding requirements of the Forum Secretariat and SOPAC, it is important to remember the isolation of the individual Island States, and their remoteness from the aid agencies that support them. In this context, the existence of a Regional centre of expertise that can be called upon for advice and assistance by the different project sponsors and Island State Governments, would appear to be invaluable.

For Kiribati, the Regional approach also allowed SEC to establish itself as a regional manufacturer and supplier of PV system controllers and dc/dc converters, which has provided the company with an on-going source of income, and the opportunity to deploy its staff on local manufacturing and component testing. This has benefited the senior staff and technicians at SEC, who now have a better understanding of how these devices work in their own systems.

2.2.8 Interventions from other donors in Kiribati

Apart from the early PV systems installed during the 1980’s under the PREP programme, most of which failed within the first few years of operation for reasons which are now well understood, the first PV solar home systems of the latest generation in Kiribati were installed under a pilot programme by JICA, who provided 56 high quality PV systems for individual houses on North Tarawa. The designs appear to be very expensive, but the quality is good and they are still working today. The JICA systems are now maintained by SEC in the same way as the PV follow-up systems.

PV powered water pumping systems have been installed in several of the schools in the outer islands by UNCDF. These systems include a small surface mounted pump, a large plastic cistern, and distribution pipework to a series of taps around the school campus, so that water can be used by the children for drinking close to their classrooms.

PV systems for lighting and powering vaccine refrigerators in the medical centres of each of the outer islands were installed about 8 years ago with funding from Canada. These are now maintained by SEC under contract to the Ministry of Health.

Donor aid is provided for other projects in Kiribati by Australia, France, Canada and Japan. For the future, a draft Memorandum of Understanding (MOU) has been drawn up by Australia and France, with a view to implementing a new renewable energy programme in the Pacific region. It has been agreed that the host for this regional programme will be SPC, but details have yet to be finalised. In addition, a MOU has been drafted by the French for further PV projects in Kiribati. At the time of our evaluation mission, there remained some points of concern to the Government of Kiribati and it had therefore not yet been approved.

2.3 TUVALU

Tuvalu is an independent constitutional monarchy, for which the British monarch is the titular head of state. It consists of a group of nine coral atolls, all of which are inhabited, with a total population of around 10,000.

Its GDP per capita in 1995 was ~1,250 AUD, and its average electricity consumption per capita was approximately 1 kWh per day (1990).

The Tuvalu Trust Fund provides the government with a sustainable long-term source of income that is used to underpin recurrent expenditure, which includes support for the basic development needs of the communities living on the outer islands.

We estimate that typical households on outer islands comprise 6-7 persons and have incomes in the range 150 - 300 AUD/month. Families with seamen have higher incomes, and the numbers of seamen from Tuvalu have increased significantly in recent years. Nevertheless, these income values are broadly consistent with the Government statistics, which show an average household income in the outer islands of approx. 240 AUD/month in 1994 and inflation running at less than 10%.

2.3.1 Problems and actors identified in Tuvalu

Problems

Like Kiribati, the key problem for Tuvalu is its remoteness, which makes transport very expensive and communications difficult. Tuvalu does not suffer from drought to the same extent as Kiribati, and sanitation is less of a problem because the population relies on the collection of rainwater for almost all of its water supplies, though hygiene remains a problem and dysentery is common. The majority of houses have metal roofs for the collection of rainwater and large cisterns to store it in.

Being further South than Kiribati, Tuvalu is subject to periodic cyclones which in the past have caused extensive damage to all forms of buildings, trees and infra structure.

The high temperatures, frequent rain and proximity of the ocean to all parts of the islands result in a very humid environment and the air frequently carries saline spray, which causes rapid corrosion of all metallic objects and system components. Electronic equipment and computers can suffer particularly, not only from the high humidity and temperature, but also from airborne fungi which, for example, can quickly destroy floppy disks.

Transport is only possible to the outer islands of Tuvalu by ship (mainly the inter-island vessel Nivaga II), which is typically scheduled to visit each island about once per month. At the time of our evaluation mission, the Nivaga II was in Fiji for maintenance, and the only means of reaching the outer islands was either the Police Patrol boat or a small fishing boat. Long term maintenance on the Nivaga II is needed at least on an annual basis and breakdowns are not infrequent. There are no operational airstrips on the outer islands of Tuvalu (though there are abandoned airstrips left over from World War II on one of the uninhabited islets of Nukufetau and on the main islet of Nanumea), so transport to these islands is far from reliable. Transport on these tiny islands is either by motor cycle, or more commonly by bicycle.

Communications with the outer islands of Tuvalu has recently been enhanced by the installation of solar PV powered telephones. These are relatively new, and teething problems were still being experienced during our mission. However, it was possible to call the outer islands from the central telephone office in Funafuti.

Key actors in the PV sector

The PV sector involves the following key organisations in Tuvalu :

Tuvalu Solar Electric Co-operative Society (TSECS): TSECS was initially set up in the early 1980's and is still the only PV supplier and maintenance company in Tuvalu. It is owned by its membership, which consists of the PV system users in each of the 8 islands, and is managed by small team comprising a General Manager, and two technicians based in Funafuti. A Management Committee is made up of one representative from each of the islands, and the Society reports directly to the Ministry of Tourism, Trade and Commerce. The Ministry of Finance and the Ministry of Works, Energy and Communications are represented on the Management Committee of TSECS, and the Ministry of Tourism, Trade and Commerce (Registrar of Co-operatives) is Secretary on the Board of TSECS. For further details see Appendix 11.

Ministry of Works, Energy and Communications: This Ministry has responsibility for energy planning in Tuvalu, and Mr Isaia Taape, the Energy Planner from the Ministry participated in the evaluation mission to the outer islands.

Ministry of Tourism, Trade and Commerce: This Ministry, led by the Minister of Finance, is responsible for all Co-operative Societies in Tuvalu. The Registrar, who is based in this Ministry, is responsible for overseeing the accounts of the TSECS.

Ministry of Finance : This Ministry is responsible for National Planning and has extensive budgetary and financial involvement in projects benefiting from international aid. This Ministry would oversee any future changes to the status of the TSECS, for example were it to be restructured as a Government-owned Corporation.

Prime Minister's Office - Special Services Unit : This unit takes charge of special projects for the Prime Minister. At the time of the evaluation mission, it was staffed by one ex-patriate (James Conway) and one local official. This unit might provide the focus for the future re-structuring of TSECS.

Ministry for Health, Women and Community Affairs : This Ministry is responsible for health clinics on each of the islands and employs TSECS to maintain the PV lighting and vaccine refrigerators in these clinics.

Tuvalu Electricity Corporation (TEC) : This Government Corporation is responsible for power generation and for the electricity grid on Funafuti. It has ambitions to install and operate grids on the outer islands, but it is not clear that the necessary financing will be made available for this. Moreover, the results of our evaluation suggest that PV electricity services are better suited to the needs and resources of the communities on the outer islands than grid power. TEC has also proposed itself as the future owner of the business currently managed by TSECS. However, in the light of the challenges which face TEC in providing a reliable and commercially viable grid supply to Funafuti, it would appear to be better to let TEC focus on its core business and to restructure TSECS as a separate government owned Corporation.

Island Councils: Each of the outer islands of Tuvalu has an Island Council, staffed by one or more full time public servants, who manage the civic business of the island. They have a key role in the development of their communities, and provide important official links with the Government.

Tuvalu Co-operative Society : The TCS owns and operates retail outlets on Funafuti and the outer islands, and is by far the largest single wholesaler and retailer in the country. It sells a wide range of products, including foodstuffs, clothing, household appliances, light bulbs and car batteries. It also manages the shipping of most of the goods to and from the outer islands, including liquid fuels, and provides its members with Banking facilities, screens films, hires out small generators, operates a butchery, markets local produce, and manufactures small goods.)All of the members of TSECS are also members of TCS, so it has been tentatively suggested as a potential future host for TSECS. However, this suggestion has not been taken further here on the grounds that the management of TSECS is a highly specialised utility operation which is very different from that of a retail business.

BP Oil : BP has the monopoly on wholesale oil supplies in Tuvalu. It sells to government, TCS, small retailers, TEC for power generation, and jet fuel to Air Marshall Islands.

Tuvalu Gas : This is a small distributor of LPG, which is supplied by Fiji gas in one ton bulk containers. LPG has been available in Tuvalu for many years but, since the sale and distribution was privatised in the early 1990's, the market has begun to grow more rapidly.

2.3.2 Beneficiaries of the PREP PV follow-up project in Tuvalu

Since 1984, more than 400 solar lighting systems have been provided to individual households in the 8 islands of Tuvalu, but most of the early systems have had to be refurbished or upgraded owing to the initial use of poor quality system components. The early systems also suffered from cyclone and storm damage, had undersized PV arrays and experienced high rates of tampering, which together led to relatively high failure rates. In the PV follow-up project, about 60 new PV lighting systems were installed, and all of the existing 226

PV lighting systems were up-graded. At the same time, a further 100 PV lighting systems were installed with funding from the EC National Lomé III programme. Unfortunately, the records of TSECS are so disorganised or non-existent that it is difficult to ascertain exactly which systems were up-graded and what exactly was installed or replaced in each system.

To become a member of TSECS, each family had to pay a deposit of 50 AUD to reserve a PV lighting system and demonstrate its willingness to pay the monthly fee once installed, which is currently 7 AUD for one light or 7.6 AUD for two lights, or 8 AUD if power is also connected to a radio. Except for the deposit requirement , the systems were made available on a first come - first served basis, and there are still long lists of people waiting for a PV system to be installed.

The PV follow-up programme also provided 8 PV vaccine refrigerators, one each for the medical clinic on each outer island, and 7 larger PV systems which included domestic refrigerators. The latter were installed in the houses of the technicians on each island to serve as pilot projects for demonstrating the performance of higher powered PV systems.

The funding and experience from the PV follow-up project should have provided important benefits to the Tuvalu Solar Electric Co-operative (TSECS), and helped it to become better established and more sustainably run organisation. More recent technical assistance to produce a policy paper, to review the structure of TSECS and to study grid connected PV should also have helped to strengthen TSECS. However, this has not been the case, due largely to poor management and management turnover. Nevertheless, the PREP and its PV follow-up project have permitted TSECS to continue to supply an electricity service to rural households, create and retain a number of local jobs, including 7 field technicians (one in each of the outer islands), and a full time staff of 3 to manage the business in Funafuti.

2.3.3 Energy needs of the rural populations in Tuvalu

The energy needs of the rural populations in the outer islands of Tuvalu are still low, the main requirements being for lighting and cooking. However, there is a growing demand to power radios and videos, and a demand to power televisions can be expected very soon, since TV broadcasts are already available in Funafuti (a local repeater for satellite channels has been operating for the last year and a half). This potential growth in energy demand was recognised at the time of the PV follow-up project, and was the reason for installing the 7 larger PV pilot plants with domestic refrigerators in the outer islands. However, TSECS has been in such disarray in recent years that no useful results have been obtained from these pilot systems. Most of the domestic refrigerators appear to have broken down and, with the current lack of funds, there is little will or interest in revitalising the pilot systems for demonstration purposes.

Some shops on the outer islands have begun to install refrigerators and freezers powered by their own small diesel or petrol generators, so there is already evidence of an emerging demand for domestic refrigeration and freezers in the not too distant future. This was also born out by the findings of the PV inspection visit in 1995 (documented in the Project Final Report). However, at the present time, there is little need for refrigeration since most of the food is in the form of freshly caught fish, freshly prepared local vegetables, rice and tinned foods. Fresh meat is available for special occasions from chicken and pigs raised by individual families. Any left over food from the day is distributed to the extended family, friends, and neighbours or fed to the pigs, chicken and other animals.

In recent years, there has been a growth in the demand for transport fuels, largely for motor cycles and a small number of outboard motors for small fishing boats. This demand is significant when considered in terms of the need to supply sufficient drums of fuel each month from the main island, but it is unlikely to increase dramatically in the near future.

2.3.4 Use of energy in Tuvalu

Energy is available in Funafuti in the form of grid electricity, kerosene, benzene, diesel, LPG and traditional biomass (coconut husks). Energy is used largely for cooking, lighting, refrigeration, entertainment (radio, TV, video, etc.) and transport. On the outer islands, with the exception of Vaitupu, there is no grid electricity, and no routine supply of LPG. Supplies of liquid fuels to the outer islands are also unreliable.

A small low voltage grid has recently been installed in Vaitupu, using some diesel generators that were left behind at the end of a JICA project. This provides electricity for only a few hours per day, mainly in the morning and the evening, and charges for some households are as high as 30 AUD per month even for this limited service. Nevertheless, the scheme, which is owned and operated by the Island Council, is operating at a loss of about 200 AUD per month.

Energy (other than solar) on the outer islands is only available in the form of LPG and liquid fuels, and the supplies of these fuels are not very reliable. Cooking is mainly done by burning coconut husks, though some of higher income families use kerosene when it rains (there is much more rain in Tuvalu than in Kiribati).

Non-solar lighting is by kerosene pressure lamps or wick lanterns. We estimate that household expenditure on energy in the outer islands is typically 10-20 AUD/month (excluding fuel for motor cycles and outboard motors).

2.3.5 The energy situation in Tuvalu

The Tuvalu Electricity Corporation (TEC) operates the electricity grid on Funafuti. It has no other grids at present, although it operates small outstations at the Tuvalu maritime School on Amatuku and the Secondary School on Vaitupu. However, it is ambitious to establish and operate grid power on the outer islands.

Details of the oil and gas prices in Tuvalu are summarised in Appendix 12, together with some historical data on overall energy consumption.

The real costs of fuel on the outer islands are very high, largely because of the costs of transporting the fuel, first to the main island by coastal tanker, and then onwards to the outer islands. Liquid fuels are transported in 200 litre drums to the outer islands by ship (normally the Nivaga II), and the drums are then transferred by small boat to the beach or floated to the shore, from where they are rolled up the beach to a holding compound. As one might imagine, this exercise is not without its problems. Most drums can only withstand a few trips over the coral reefs and up the beach before they begin to leak. Similarly, they cannot resist being left repeatedly to heat up in the midday sun without leakage. Rapid rusting and corrosion is another problem. As in Kiribati, there is a continuing shortage of drums, and a frequent shortage of liquid fuels on the outer islands. This situation is unlikely to change in the near future, since the size of the market for liquid fuels on the outer islands is likely to remain very small, and therefore there is little incentive for investment in better fuel transportation or distribution infra-structure.

Liquid fuels are supplied to Tuvalu by BP, and LPG is supplied by Fiji Gas through Tuvalu Gas. The Tuvalu Co-operative Society manages most of the retail outlets on the outer islands where liquid fuels and dry cell batteries can be purchased. Energy prices are the same on all of the islands of Tuvalu because of a freight equalisation levy imposed and applied by the TCS. Much of the basic infrastructure remains from the colonial era (pre-1978). That which has been up-graded or newly built has been done largely through aid from bilateral donors.

2.3.6 Coherence of project objectives vs Tuvalu government objectives

The objectives of the original PREP project - to reduce dependency on fossil fuels and establish the suitability of renewable energy technologies for the region - were in line with those of the Tuvalu Government at the time, and were broadly maintained for the PV follow-up project. However, some more specific objectives of the Tuvalu Government have also been addressed by the PV follow-up project, notably rural electrification with the aim of improving the quality of life and enhancing development on the outer islands and, in so doing, reducing migration to the main island (see section 2.4). The PV follow-up project built on the experience of TSECS, and provided some institutional strengthening and training during the project implementation stage. However, since TSECS is a largely independent co-operative organisation, the Government was not directly involved with either its operation or management.

The Government of Tuvalu in addition has recently adopted its first comprehensive energy policy statement, prepared in conjunction with the Energy Unit of the Forum Secretariat, now located at SOPAC (since January

1998). The policy encourages the use of renewable energy, particularly for rural electrification, which is in line with the objectives of the PV follow-up project.
The annual speech by the Governor General in June 1998 specifically referred to the importance of restructuring TSECS.. During our evaluation mission, the options for achieving this restructuring were discussed at length with the government officials in the Ministry of Works, Energy and Communications, in the Ministry of Finance, and in the Prime Minister's Office. These options have also been explored and documented in detail by Solomone Fifita in a recent review of TSECS, published by SOPAC. Essentially, 3 options are under discussion :

a) **Revitalise the existing co-operative, by appointing new staff and trying once again to make it work effectively.** This option has already been tried several times and has not worked. The reason is essentially that there is a basic short term conflict of interest for the members of the Management Committee who want to minimise the monthly fees for their members, when in fact the business needs higher fees to become sustainable, ie to break even in the long term.

b) **Merge the TSECS with TEC and ask the General Manager of TEC to manage both enterprises at the same time.** It is widely recognised that the General Manager of the TEC has enough of a challenge to ensure that the TEC becomes financially viable, whilst at the same time improving the reliability of the electricity supply to Funafuti. This is not the time to deflect TEC from its core business by adding another business which is in need of major restructuring and re-financing.

c) Dissolve the existing co-operative society and establish a new Government owned Corporation, with a new Board of Directors consisting of senior Government officials and a representative from the National Bank of Tuvalu. This is the preferred option. It is expected that this option would attract a new injection of aid funding with a view to refurbishing the existing PV systems, training new managers and technical staff, and establishing comprehensive stocks of spare parts, proper stock control, accounts and business management systems. The key issues are : (1) to identify suitable candidates to take on the new roles of Chairman and Executive Manager, (2) to obtain Government agreement to inject about 20,000 AUD to repay the membership fees to existing members of the co-operative, and (3) to obtain Government agreement to inject an appropriate amount of working capital to establish the new Corporation on a sound financial footing. Nevertheless, the opportunity should be taken to build on the earlier successes of the co-operative. It is envisaged that the Chairman of the Board would be an honorary position, nominated by the Minister of Works, Energy and Communications, whilst the new Executive Manager would be a skilled professional, who is experienced in international procurement and all-round business practices.

2.3.7 Relevance to Tuvalu of the Regional approach

At the time of implementing the PREP PV follow-up project, there was not sufficient local expertise in Tuvalu to manage a project of this scale, so external assistance was essential. Economies of scale were obtained by employing this assistance for the benefit of several Island States at the same time, especially for the work involving training and the development of local skills. Similarly, economies were achieved by tendering for the bulk purchase of standard items, such as PV modules, batteries and cabling.

The PV follow-up project benefited from the involvement of the Forum Secretariat, whose Energy Division provided technical and management expertise on a Regional basis. This expertise has now been transferred to SOPAC, who still provide a valuable service in bringing together the experiences of the different Pacific Island States, and facilitate the cross-fertilisation of ideas though regular meetings and exchanges of personnel. When considering the future funding requirements of the Forum Secretariat and SOPAC, it is important to remember the isolation of the individual Island States, and their remoteness from the aid agencies which support them. In this context, the existence of a Regional centre of expertise which can be called upon for advice and assistance by the different project sponsors and Island State Governments, would appear to be invaluable.

For Tuvalu, the Regional approach encouraged TSECS to purchase locally produced PV system controllers and dc/dc converters from SEC in Kiribati, which ensured that they would be suited to the local climatic conditions and could be repaired in the Region.

2.3.8 Interventions from other donors in Tuvalu

In addition to the aid provided by the PV follow-up project, Tuvalu has received donor aid for PV systems from a number of sources, including :

- the USA - USAID and Save the Children Federation in the early 1980's
- France - provided replacement controllers and batteries in 1987
- Canada - provided 36,000 AUD for 101 new controllers and 61 new batteries in 1996
- the Forum Secretariat's Small Island State's Development Fund (Small Energy projects Programme) funded the construction of the TSECS head office in Funafuti, to which power is supplied by a dedicated PV system with an inverter. The building is not grid connected.
- the Lome 3 PREP provided funds for a local training workshop for the outer island technicians in Funafuti. It also funded the participation of Tuvalu and Kiribati technicians on PV training courses in Fiji and Bangkok.
- JICA provided opportunities for technicians from both Kiribati and Tuvalu to undergo 3 months training in Japan on the technical and management aspects of PV.
- SOPAC reviewed the sustainability of the TSECS and provided a training attachment to the SEC for the Tuvalu Energy Planner.
- SOPAC continues to provide information, follow-up assistance and advice on request
- TSECS is currently hoping to receive new aid from Japan, though this is yet to be confirmed.

2.4 LOGICAL FRAMEWORK

As there was no logical framework drawn up at the beginning of the PREP PV follow-up project, a logical framework has been reconstructed as part of this evaluation to reflect the original objectives, project purpose, expected results and planned activities of the project.

During the course of its implementation, the PV follow-up programme evolved to address the more recent objectives of the two governments concerned, and a slightly different Logical Framework therefore applies to the project as it was actually implemented.

Two logical frameworks are therefore presented in Appendix 3. The first is a ***reconstructed Logical Framework*** which is based on the original objectives of the PREP, and the second is a ***new Logical Framework*** which applies to the more recent objectives of the governments concerned.

The following points are a summary of the information given in these logical frameworks.

Overall Objective
The initial objective in the PREP programme was to reduce dependence on fuel imports in the region, and to prove the suitability of renewable energy technologies in the region. The PREP PV follow-up project followed on from this in that it's objective was to achieve rural electrification based on indigenous natural resources (not on petroleum based fuels).

Project Purpose
The purpose of the PV follow-up project was to install a sustainable source of electricity for rural households. It was hoped that the PV systems would prove to be an appropriate source of electricity which is sustainable environmentally, economically and technically in the conditions found in the South Pacific.

Results

The PV follow-up project was expected to contribute to rural development. In particular, it was hoped that it would:

- provide household light in the evenings; which would improve living standards and allow commercial activities to take place after dark (e.g. making handicrafts to sell, preparing fish to sell, keeping shops open for business), which would in turn reduce poverty;
- provide electricity in medical clinics (in Tuvalu) for lighting and vaccine refrigerators, which would improve health;
- provide dc power for small appliances such as radio/cassettes and CB radios, which would improve communications and leisure facilities;
- produce more skilled and trained people, who could contribute to future development.

Activities
The activities planned to be undertaken in the PV follow-up project were:

- to supply and install PV systems;
- to develop supporting infrastructure to help make the technology sustainable (policy, finance, operation and maintenance);
- to provide training and education to managers, technicians and users.

Objectively verifiable indicators
It is not clear how it was originally planned that the project should be assessed and its results measured, and many of the measures needed for such an assessment are not readily available. Nevertheless, suggestions for parameters by which the project could be assessed have been listed in the logical frameworks in the objectively verifiable indicators column, and as far as possible these have been investigated as part of this evaluation, notably:

- Reduced petroleum dependence - fuel ratios, amounts of fuels imported, estimates of kerosene saved by PV lighting.
- Improved health - lower sickness levels and reduced numbers of burns from kerosene lamps, etc; longer life expectancy (long term data needed).
- Improved education - increase in literacy, hours of study per week.
- Reduced poverty – jobs created and commercial activities enhanced by PV systems.
- Percentage of rural households with electricity – number, location and when PV systems are installed.
- Willingness/ability of people to pay - numbers of 50 AUD deposits made for new PV systems, fee payments outstanding, size of fees in relation to monthly household income and other outgoings.
- Services provided by PV - range of appliances being used (electric lights, radio/cassette, CB radio, refrigeration, etc).
- Community systems installed – lighting in health clinics, schools and community centres; water pumping systems in schools; refrigeration in health clinics.

Sources of Verification
The main sources of information which can be used to assess whether or not the project was a success in achieving its planned results are:

- existing literature (reports, notes and communications);
- information collected and discussions held during the ex-post evaluation mission to the region (29 September to 6 November 1998).

Assumptions

The following assumptions were made in the logical frameworks:

- Rural electrification will lead to an improvement in the quality of life and accelerate rural development;
- PV is economically competitive with alternative forms of electricity available in the outer islands;
- PV is a convenient and financially competitive means of lighting compared to alternatives available in the outer islands (requires ~1000 household PV systems to be installed);
- PV is an appropriate technology for the region;
- There would be proper installation, operation and maintenance of PV systems;
- There would be access to any spare parts required;
- The environmental impacts of PV would be taken into consideration and managed appropriately;
- There would be adequate availability of appliances such as light tubes, ballasts, radio/cassette, CB radio, TV/Video, etc and users would be able to purchase them locally.

Preconditions

In order for the project to be a success, there needed to be agreement on the programme objectives, funding, implementation and management between the EC, the National Governments of each country and the regional organizations concerned. There also needed to be involvement of and cooperation with the local communities and system users.

3. Project Implementation

3.1 PROJECT PREPARATION AND DOCUMENTATION

The PV follow-up project was implemented as part of the Pacific Regional Energy Programme, in response to requests from the governments concerned and in the light of the problems which had been experienced with the earlier projects. It therefore did not benefit from the full rigours of the EC's project cycle management procedures, and as a result there was no initial Logical Framework for the project. Nevertheless, the project was extensively documented, and comprehensive sets of documentation were studied by the evaluation team in Brussels, Fiji, Kiribati and Tuvalu. Logical Frameworks were drawn up for the project as part of this evaluation, as discussed in Section 2.4 (above), and these are presented in Appendix 3.

Based on our studies of the documentation and discussions during the evaluation mission, an overview of the events that led up to the PV follow-up project and the different stages of project implementation have been prepared in the form of a Time-line, which is presented in Appendix 4.

3.2 ROLE OF REGIONAL ORGANISATIONS AND GOVERNMENTS

The project was supported by a small team of experts from the Energy Division of the Forum Secretariat (FSED), which has subsequently been closed and responsibility for energy projects transferred to SOPAC. (Note : the Secretariat retains a role in energy policy / regulation at a regional level as part of its economic reform mandate.) The knowledge and expertise of this team, together with their independent status allowed them to provide assistance to the Regional delegation of the EC as well as to the governments of the countries concerned and the solar companies.

The Energy Planning teams of the Governments in both countries were closely involved with the project, and gave it their full support.

All of the key stages of project expenditure and advancement were monitored and documented by the regional team as well as the local managers in the countries where the equipment was being installed. Extensive sets of countersigned Component Acceptance documents were archived both in Fiji and in the islands. In Tuvalu, these documents were stored in the energy planning office of the Ministry of Works, Energy and Communications. In Kiribati, the documentation was archived with the Solar Energy Company.

There was no significant local private sector involvement in the project in either country, since the main local actors were the solar companies themselves, which in Kiribati is Government owned and in Tuvalu is a co-operative society. However, the local communities were involved to a degree through the co-operative in Tuvalu, since all of the beneficiaries were members of it. Also, the Island Councils in both countries provided local guidance and support during the implementation stage.

Other important benefits from the regional approach were economies of scale in the international procurement of modules and batteries; and similar benefits in the local manufacturing of controllers, which were adapted to meet the harsh climatic conditions of the region.

Shortly after the project was completed in May 1995, an extensive Final Report was prepared by the project consultant, who had provided much of the guidance and training to the teams involved. This Final Report has also provided an important input to the ex-post evaluation presented here.

3.3 PROJECT ORGANISATION AND TRAINING

The main PV follow-up project involved four main stages of implementation, each of which had an associated package of training, as follows :

1. Tender

2. Delivery and testing of equipment
3. Installation
4. Operation and maintenance

The training which was initially provided as part of the PV follow-up project is now being continued as far as possible in-house by the staff of SEC in Kiribati, but no training has been done in Tuvalu in recent years owing to lack of funds and external assistance.

More recently, as the operation of the systems has continued, new stages of the project have begun to emerge, and it has become clear that additional external assistance is now needed for more advanced training to cover these stages, namely

5. Technical trouble shooting for failures in the older systems
6. Business and accounts management, including international procurement of replacement system components and stores/ stock control
7. Coaching / training of field technicians by local senior technicians

3.4 FROM TENDER TO INSTALLATION

Tendering was based on hardware supply to the local solar companies, and did not require international suppliers to commit themselves to more than conventional component warranties. This was surprising at first to the evaluation team, because experience elsewhere had suggested that the local teams would require long term technical support from their suppliers. However, after discussions with the local teams it became clear that the approach adopted for the PV follow-up project was based on experience from earlier EC PV projects in the region.

The earlier projects had demonstrated that the large international suppliers were based too far away to provide practical support, and the local markets were simply too small and fragmented to secure any real long term commitment from them. The only reliable solution for the local solar companies was therefore to acquire expertise locally through external technical assistance and training, and to develop their own experience by installing the systems themselves.

The call for tender was therefore arranged into 12 Lots, which were awarded as follows:

Lot 1	PV modules	Poly Products (Fiji) Ltd, (Siemens M50 LS)
Lot 2	Charge controllers	SEC, Kiribati, (SPIRE design, made locally)
Lot 4	Night lights	SEC, Kiribati, (SPIRE design, made locally)
Lot 3	Lights	CommPac, Fiji (Solagen/Philips)
Lot 12	Solarimeters	CommPac, Fiji (Haenni)
Lot 5	Switches	Soler Energie, Tahiti (Legrande)
Lot 6	Cabling	Soler Energie, Tahiti
Lot 7	100 Ah batteries	Soler Energie, Tahiti (Oldham)
Lot 8	425 Ah batteries	Soler Energie, Tahiti (Oldham)
Lot 9	Refrigerators	Soler Energie, Tahiti (Total Energie)
Lot 10	Tools	Soler Energie, Tahiti (Makita)
Lot 11	Test equipment	Soler Energie, Tahiti (ITT Metrix)

All of the equipment delivered to the islands was inspected and acceptance tested on the main islands before being shipped to the outer islands. After it was installed, comprehensive inspection missions were carried out by the project consultant together with the responsible team of technicians (and in the case of Tuvalu an on-site EU Technical Assistant) to check that the systems had been properly installed. A detailed report was prepared on each of these inspections, and a summary of the findings is included in the project Final Report of May 1995.

3.5 OPERATION AND MAINTENANCE

The project established a formal "user's contract" between the solar company and each user, specifying what was to be expected from each party (copies were supplied to all users and technicians). The PV equipment, including the PV modules, battery, controller and wiring would remain the property of the PV Utility company, whilst the lights and internal wiring were to become the responsibility of the users after a one year warranty period. The responsibility of the solar company for routine maintenance and the requirement that no unauthorised appliances should be connected by the user were included to ensure a long term and sustainable PV Utility service for the users with a high reliability at minimal cost.

3.6 FOLLOW UP

The initial PV follow-up project was followed by a regional capacity building and training project, which included some additional PV training. However, it was probably wise, before installing any more PV systems to wait for long enough to establish whether or not the PV Utility scheme which had been funded under the PV follow-up project is likely to be sustainable in the long term.

The findings of this Ex-Post Evaluation, which was carried out approximately 4 years after the installations were completed, suggest that the PV Utility scheme, which was implemented through the PV follow-up project, does have the potential to be sustainable. However, a number of steps must be taken to realise this potential, especially in Tuvalu, and these are outlined in the Recommendations of this report in Section 8.

4. Results and Effectiveness

The overall effectiveness of the PV follow-up project can be assessed in terms of the benefits produced for the system users in the outer islands. Essentially, these depend on the quality of the services produced by the PV systems, their reliability, and the quality of the maintenance.

Information which allows these benefits and services to be assessed was gathered directly from the users during the visits to the outer islands, which formed a major part of the evaluation mission. Details of the findings from the visits to individual users are presented in Appendix 7.

4.1 BENEFITS AND SERVICES

4.1.1 Services which help to tackle development priorities

In order to understand better the significance of the benefits and services that PV electricity systems can bring to rural communities, it is important to see them in the context of the communities' development priorities. The development priorities of the outer islands in Kiribati and Tuvalu are summarised in Table 4.1 below, which also shows how PV electricity services can help to tackle these priorities.

Table 4.1 Development Priorities for Outer Island populations in Kiribati and Tuvalu

Priority issue	Related issues	Services from PV electricity
Health	• Clean water • Sanitation • Medicine • Food	• Water pumping, treatment, desalination • Lighting and video for hygiene classes • Lighting, refrigeration and sterilisation for medical centres • Lighting for food preparation and consumption, and refrigeration/freezing for storage
Education/ cultural heritage	• Religious education (good clean living/culture) • Academic education • Reducing women's drudgery	• Good quality lighting for reading/study/community meetings • Lighting for study and power for computing, printing, photocopying • Washing machine, iron, light, kettle
Communications	• CB radio, telephone & radio (to listen to national announcements/messages)	• Power for these appliances

Table 4.1 (continued)

Priority issue	Related issues	Services from PV electricity
Community identity and cultural/leisure activities	• Meetings/social activities in maneabas / falekaupule • Cassette/radio, video/TV, film	• Lighting for social activities (music, dancing, singing, playing games, crafts) • Power for these appliances

Transport	• Isolation, infrequent deliveries of food, liquid fuels and post. • The government has to subsidise transport (sea and air) to allow people and goods to travel between the islands	• Greater reliability from PV as it is not dependent on the availability of liquid fuels, so can provide light & power even when liquid fuels have run out. • Economic source of light and power as, once PV systems are installed the volumes of equipment and spare parts to be transported to the outer islands are relatively small.

Note: This table was created from discussions held with the users in the outer islands.

4.1.2 Direct benefits from the PV follow-up systems

The benefits and services provided by the PV systems installed under the PV follow-up project for households and medical centres, are mainly in the form of lighting in the evenings for:

- Cooking and eating;
- Studying/reading;
- Tending to household chores
- Making handicrafts and sewing;
- Preparing to go fishing at night
- Preparing the night catch (salting the fish to sell or store)
- Cultural activities and socialising (e.g. meetings/discussions, singing, music, dancing, playing games)
- Tending to sick people, young children and the aged

In addition to these benefits from lighting, the PV follow-up systems also provide power for radio/cassette players, CB radios and vaccine refrigerators.

Further information on how these benefits apply to different sectors of the population is given in Section 4.4.

4.1.3 Other benefits that PV systems can provide

Additional benefits / services that PV systems can provide - and in some cases are already providing (if sized to cope with the power demands) are:

- ***Lighting in public meeting places (Maneabas in Kiribati and Falekaupule in Tuvalu)*** - at present this is mainly powered by diesel generators.
- ***Outside lighting or street lighting*** - there are already some outside lights in private courtyards and outside shops which were installed as part of the PV follow-up project, and some PV street lights were installed at the Vaitupu harbour by JICA
- ***Lighting for school classrooms and dormitories*** - the secondary schools visited during the evaluation mission were asking for this
- ***PV powered water pumping*** – this is already being installed in Kiribati by the UNCDF
- ***Telecommunications*** – these are already being powered by PV generators in most cases
- ***Computers and printers in schools*** – there is one school in Nonouti that has already set up a PV system to do this.

4.1.4 Benefits from combining PV and small diesel generators

PV systems have an important role to play in the provision of electricity services in the outer islands in Kiribati and Tuvalu, but small stand alone diesel / petrol generators and diesel-based mini grids can also make an important contribution. For example, appliances which use a lot of power (>500 W) but are used infrequently or are moved around and used in multiple locations (e.g. washing machine, video/TV, film projector) can often be run more economically from a portable diesel or petrol generator. In the context of the outer islands, the overall aim of a rural electrification programme should not be to use only PV or only diesel systems, but rather to use both (as appropriate) to complement one another.

4.1.5 Indirect benefits from the PV follow-up programme

A number of important indirect benefits have arisen from the installation and use of PV systems in Kiribati and Tuvalu, including the following:

- ***Employment*** **-** SEC has created 13 full time and 14 part time jobs in Kiribati and TSECS has created 10 full time jobs in Tuvalu (see Sections 4.2.4 and 4.3.4). Less tangible economic activity has resulted from the collection of the monthly PV Utility fees and periodic PV installation works.
- ***Technical skills / capacity building*** **-** The staff of SEC and TSECS have benefited from a series of training courses, as well as on-the-job training from the project consultant during the course of the project. As a result, there is now a nucleus of expertise in PV technology amongst the technicians in these islands, and unique experience in the operation and management of a rural PV Utility.
- ***Reduction in fossil fuel imports*** **-** We estimate the annual savings in fossil fuel imports which have resulted directly from the PV follow-up programme to be about :
  40,000 AUD per year in Kiribati
  50,000 AUD per year in Tuvalu,
  This corresponds to a total of 90,000 AUD per year, or over **300,000 AUD** since the installations were completed in mid-1995. (see Section 6.2.1) .
- ***Reduction in CO_2 emissions*** : Based on an approximated average conversion factor of 2.5kg of CO_2 per litre of fuel saved and the estimated combined fuel savings from Kiribati and Tuvalu of 163,000 litres per year, the overall CO_2 savings arising from the PV follow-up project may be estimated as about **408 tons per year**. (Bearing in mind the very approximate nature of our estimates for the fuel saved and the relatively small amounts of CO_2 produced during the manufacture of the components concerned, it is reasonable to neglect the CO_2 which was consumed in the manufacture of both the PV system components and the kerosene lamps, and the CO_2 produced during the transporting of both the PV systems and the fuel to the outer islands.)

4.2 EFFECTIVENESS INDICATORS FOR KIRIBATI

4.2.1 Number and type of equipment installed and working

The Final Report on the project (1995) contains a listing of all the installed PV systems following a detailed inspection mission by the project consultant. Our visits to the islands in Kiribati provided us with the opportunity to study only a sample of the installed systems, but sufficient to give us confidence in the Final Report.

The overall aim of the PV follow-up project in Kiribati was to install a total of 250 PV household systems in the outer islands as follows :

Nonouti (75 systems)

Marakei (75 systems),

North Tarawa (100 systems)

The evidence obtained during the mission confirmed that these systems were installed as planned, and more than 95% of the systems were found to be working well.

Each PV system in Kiribati was more or less identical, having the following key components:

Table 4.2 Key components of PV follow-up systems in Kiribati

Component	No	Supplier	Rating	Design life yrs.	Comments
PV module	2	Siemens	50 Wp	20	Good quality, but size of terminals in connection box is too small for power cabling
Battery	1	Oldham	100 Ah	5	Good quality, with transparent casing for easy maintenance.
Charge / discharge Controller	1	SEC		8	1st model had steel screws, which corroded in box lid. 2nd model with plastic screws was better.
Cabling					External quality, with special cable for underground sections.
Cable connections					Screw terminal blocks, with plated steel screws which corroded quite quickly.
DC/DC converters	1	SEC	can be adjusted	8	Units assembled in Kiribati. Very simple and rugged design.
Lights	3	Independent Power, New Zealand Ltd		5	Open white reflectors, with replaceable ballasts which could eventually be made in Kiribati

Table 4.2 (continued)

Component	No	Supplier	Rating	Design life yrs.	Comments
Night lights	1	assembled by SEC	0.5 W	15	Most users would like them to be brighter
Light bulbs	3	Philips PL	7W or 11 W	8000 hrs	Robust and seemed to be working well.
Light switch	3	Legrand	240 Vac (5 A at 12 Vdc)	8	Quality of switches was disappointing, and some had already failed from corrosion

SEC owns and is responsible for maintaining all of the PV system components as far as the light switch or dc/dc converter for the radio. After 1 year of warranty, the users are responsible for the light fittings and for replacement of the light bulbs.

The findings from visits made to individual houses during our evaluation mission are presented in Appendix 7. These confirm that the majority of the systems were found to be working well.

4.2.2 PV System sizing in Kiribati

The methodology used by the original PV follow-up project team is described in detail in their Final Report of May 1995. Rather than attempting a critique of their approach, it was decided for the purposes of this evaluation to produce an independent estimate of the required system size, and then to compare this with the sizing which was actually adopted for the project. Our independent sizing estimates are shown below:

Estimated energy demand : Several of the households visited had replaced their original 7 W lamps with 11 W lamps, so our estimate for the required system size is based on the real situation which we found in the field. Similarly, we found that the radios in use were rated at 16 W rather than the 15 W which was estimated by the project team. We therefore estimated the useful energy demand from the PV systems installed in Kiribati at 299 Wh/day (see below), which is somewhat higher than the 224 Wh/day, estimated by the original project team.

Table 4.3 Estimated energy demand in Kiribati

Energy demand	**Wh/day**
3 lamps @ 11 W operating for 6 hours	198
1 radio @ 16W operating for 6 hours	96
1 night light @ 0.5 W operating for 10 hours	5
TOTAL	**299**

Estimated PV system losses : There are many possible causes of energy losses in a PV system, and it is not easy to predict any one source of losses accurately at the design stage. However, some typical values for the most common causes of energy losses in isolated PV systems are listed below.

Experience from the last 15 years of detailed monitoring of individual solar home systems in the EU suggests that Performance Ratios (the ratio of delivered energy to the nominal output) for such applications typically vary from about 30% to 55%, and never exceed about 60% . Hence, the value of the Performance Ratio predicted below of 53% is a little high compared with the norm for such systems in the EU.

Table 4.4 Summary of PV system losses

Cause of losses	**Losses (%)**	**Effective efficiency (%)**
PV module power loss over 20 years (supplier guarantee)	10	90
Nominal module rating, temperature, and mismatch effects	10	90
Dirt on module & incidence angle effects	5	95
Cabling losses (allow for losses in connections)	10	90
Battery losses (degrades with age, allow for some overcharging)	15	85
Shading losses from nearby trees, etc	10	90
Performance ratio = delivered energy / nominal output (determined from the product of the effective efficiencies)		**53**

Estimated PV energy delivered : Based on the Performance Ratio estimated above, the energy delivered by one of the PV follow-up systems in Kiribati, may be estimated at ~ 302 Wh/day, as shown below.

Table 4.5 Estimate of PV energy delivered in Kiribati

Nominal PV array rating	= 100 Wp
Daily average solar irradiation (see Appendix 8)	= 5.7 kWh / m^2.day
Nominal PV array output (rating x irradiation)	= 570 Wh / day
Performance Ratio	= 53 %
Delivered energy (nominal PV array output x Performance Ratio)	= **302 Wh / day**

Comparison with sizing by the original project team: The simplified sizing estimates shown above are broadly in agreement with those presented by the original project team in its Final Report of May 1995, and confirm that the design used in the PV follow-up project may have a modest margin of safety when the systems are new, since some of the predicted losses occur with ageing. However, these systems are designed to last for 20 years, and the safety margin will undoubtedly reduce as the systems become older. Also, it is to be expected that a user's demand for electricity will increase during the lifetime of their PV system, for example if they purchase other electrical appliances such as a CB radio. Finally, it is good practice to provide some over-sizing of the PV array because this facilitates overcharging of the battery, ensuring good mixing of the electrolyte which helps to minimise corrosion of the plates and prolong battery life - especially after several days of bad weather.

The sizing of the batteries for these systems is broadly consistent with the analysis presented above. The Oldham batteries have a nominal capacity rating of 100 Ah (C_{10}), which at 12V corresponds to a capacity of 1,200 Wh, or approximately 4 times the daily energy demand. In order to ensure a good working life, it is normally recommended that batteries should not be cycled through more than 20 - 25 % of their nominal capacity, so this industry guideline was followed in the design used for the PV follow-up projects. Similarly, it is recommended that the battery capacity should be sufficient to accommodate typical periods of bad weather (typical periods depend on the local climate). The climate in Kiribati does not normally have extended periods without sunny days, so a battery capacity which is equal to about 4 times the daily energy demand is appropriate here.

4.2.3 Reliability of the equipment installed in Kiribati

During the evaluation mission to Kiribati, more than 95% of the PV lighting systems appeared to be working properly. Both the current users and those without solar lighting like it, and SEC keeps a waiting list of up to ~10 households on each island who have paid a deposit of 50 AUD to obtain an installation as soon as one becomes available. All of the PV systems installed under the PV follow-up project operate at 12 Vdc, and no inverters are used in these systems.

The condition and reliability of the **PV modules** (Siemens) was found to be excellent, with no evidence of failed modules amongst those supplied in the PV follow-up project, though some were mounted too flat for rain water washing to be effective. None of the PV modules installed under the PV follow-up project have yet had to be replaced. The design lifetime of the PV modules is more than 20 years, and the evidence from the mission does not suggest otherwise. In contrast, an 8 year old ARCO Genesis amorphous silicon module (300x300mm) nominally rated at ~5 Wp, which had been installed independently by a private householder, produced less than ~1.5 W in the midday sun, and showed visible signs of degradation.

The **batteries (**Oldham) were mostly in good condition, except where they had been abused or where controllers were not working properly. SEC estimate that 5-10 of the batteries, which were installed under the PV follow-up project in Kiribati, have had to be replaced to date. Since it is well known that the state of the batteries depends strongly on the quality of the maintenance which they receive, the relatively good condition of the batteries after more than 4 years of operation confirms that the maintenance is generally being well done by the SEC technicians. The design lifetime of the batteries is 5 years, and the evidence from the mission suggests that many of the batteries may well exceed this. Some batteries needed equalisation charging, though not all technicians were fully aware of this or had the confidence to do it.

The **controllers** (SEC) were generally working properly, though it was clear that the field technicians did not fully understand how they work. SEC reported that 3 of the controllers, which were installed under the PV follow-up project in Kiribati, have had to be replaced to date. The field technicians are each supplied with an AVO meter, and have been trained to use the special plug in the controller to enable a short-term "equalisation" charge. However, it was noted that the wires on this "plug" are rather weak, and once broken it is not easy for the field technicians to solder them back into position. The technicians should also be able to check for poor cable connections and other voltage drops by using their meters. The controllers have a design life of ~8 years, and most of them appeared to be able to achieve this. Some of the first generation of SEC controller boxes were difficult to open because of corrosion of the cover screws, but the circuitry inside was generally in good condition.

Most of the **cabling** was well installed, but there were several examples where connections had been made using only twisted wires rather than screwed terminal blocks, and where cables were longer than necessary - leading to unnecessary extra voltage drops. Also, some underground cabling had been laid using cable which was not of adequate quality, and which can therefore be expected to fail prematurely, but this was not a common fault.

The design life of the **light bulbs** (Philips) is 8000 hours, and many had already operated for >7000 hours. Some were beginning to fail, so they were working more or less as expected. The lifetime of **light fittings and ballasts** was said to be ~ 4 to 6 years, and some of the original lighting unit ballasts had also failed. Nevertheless, they appeared to be generally well suited to the local environment. Users seemed to be disappointed in the brightness of the night lights, which were designed to allow them to move around at night.

As might be expected, the main causes of **PV system failure** were abuse by users (lights left on all night, illegal connections of appliances such as high powered cassette radios or lights, etc), corrosion of cable connections, switches, and light fittings (due to the high humidity conditions), and shading by rapidly growing trees (eg: pawpaw).

4.2.4 Numbers of people trained and working in PV technology

The project has also permitted the Solar Energy Company to create a small number of local jobs, including 5 field technicians (one or two on each outer island) and a full time staff of 8 to manage the business in South Tarawa (for further details of SEC see Appendix 10). Part time agents are employed by SEC on 14 other outer islands. All of these staff have benefited from PV training. Those who were in post during the PV follow-up project received training at that time, and those who have joined more recently have received training through the training scheme which is still continued by the SEC senior staff. In addition, a number of field technicians have been trained but have subsequently left SEC.

4.2.5 Total energy generated in Kiribati

No monitoring of energy production was provided as part of the PV follow-up project, and the energy output from a PV system depends on many variables, including the demand of the users. However, an estimate of the overall energy production may be made using the approach presented in Section 4.2.2, as follows :

Typical PV system rated at 100 Wp
Average daily solar irradiation (Appendix 8) = 5.7 kWh/m^2
Average daily energy delivered per system ~ 300 Wh / day
Total number of systems installed = 250 systems

Total energy delivered by the PV follow-up systems in Kiribati
= 300 Wh/day x 250 systems
= **75 kWh/ day or 27,375 kWh / year.**

4.3 EFFECTIVENESS INDICATORS FOR TUVALU

4.3.1 Number and type of equipment installed and working in Tuvalu

The Final Report on the project (1995) contains a listing of all the installed systems following a detailed inspection mission. Our visits to only three islands provided us with the opportunity to view only a small sample of the installed systems, which was not sufficient to confirm the data given in the Final Report.

The overall aim of the integrated PV follow-up and National Lomé III PV projects in Tuvalu was to install about 150 new PV household systems and to up-grade 226 existing PV lighting systems - mainly in the 7 outer islands. In addition, 8 PV vaccine refrigerators and 7 larger PV systems with domestic refrigerators were to be installed, one in each outer island.

The records are so disorganised or non-existent in TSECS that it is difficult to tell exactly what was actually installed and where. However, the following list of systems operating in each island was provided by TSECS, based on the payments received from each of the outer islands. Since TSECS operates a scheme whereby payments need not be made unless the systems are actually working, the Table below is the best estimate which is currently available for the numbers of systems which are working in each island.

Table 4.6 Numbers of PV systems operating on the outer islands of Tuvalu

Outer Island	1994	1995	1996	1997	1998
Nanumea	80	80	77	74	54
Nanumaga	40	38	45	51	51
Niutao	70	70	75	80	80
Nui	49	46	42	49	49
Vaitupu	65	65	63	54	54
Nukufetau	38	39	45	45	45
Funafuti	11	11	14	17	17
Nukulaelae	38	40	40	36	32
Total	**391**	**389**	**401**	**406**	**382**

Note : The numbers vary from year to year as customers await the delivery of failed batteries or are disconnected for payment arrears.

The PV systems in Tuvalu, which were either newly installed or up-graded as part of the PV follow-up project contain components from different sources, depending on when they were installed. The key components in a typical system are listed in Table 4.7 below.

Table 4.7 Key components of PV follow-up systems in Tuvalu

Component	No	Supplier	Rating	Design life yrs	Comments
PV module	2	Siemens BP Photowatt Arco	50 Wp 42 Wp 45 Wp 35 Wp	20	Good quality, but size of terminals in connection box is too small for power cabling From earlier EC PREP From French assistance, 1987 Save the Children Fed, 1984
Battery	1	Oldham or BP solarbloc or Kobe car battery	100 Ah 100 Ah 65 Ah	5 ~5 ~1	Good quality, with transparent casing for easy maintenance. From 1990, difficult to maintain Private purchase, unsuitable for PV systems
Charge / discharge Controller	1	GIE Soler or SEC		8 8	No equalisation charge option. 1st model had steel box lid screws, which corroded. 2nd model used plastic screws.
Cabling					Mixed quality, with special cable for underground sections.
Cable connections					Screw terminal blocks, with plated steel screws which corroded quite quickly.
DC/DC converters	1	SEC	can be adjusted	8	Units assembled in Kiribati. Very simple and rugged design.
Lights	3	Standard mains units or Independent Power, New Zealand Ltd	18W	8 yrs	locally adapted ? Most houses had less than 3 lights, possibly because the technicians had shared the available units between them Open white reflectors, with replaceable ballasts which could eventually be made in Kiribati
Light bulbs	3	Philips PL	7W or 11 W	8000 hrs	Robust and seemed to be working well.
Night lights	1	assembled by SEC	0.5 W	15	Most users would like them to be brighter
Light switch	3	Legrand	240 Vac (5A at 12 V dc)	5	Quality of switches was disappointing, and some had already failed from corrosion
Vaccine refrigerator	1	BP (Danfoss compressor)	60 W	10 nom	Casing suffers from corrosion in high humidity conditions. Lifetime seems to be shorter than expected.
Domestic refrigerator	1	Solelec (Total Energie)		~5 ?	Casing suffers from corrosion in high humidity conditions. Lifetime seems to be shorter than expected.

TSECS owns the complete systems and currently still retains responsibility for the replacement of the light bulbs. It was originally intended to shift responsibility over to the users, but the Management Committee was not in favour of this, and the practice of TSECS providing new light bulbs became established. There are relatively few dc/dc converters in Tuvalu.

The number of lights provided by TSECS to their users was typically less than the three lights for which the PV systems were originally sized. Understandably, most users indicated that they would actually prefer to have three lights, and it was not clear why TSECS had not provided them, other than that TSECS did not have the money to pay for them.

Details of the findings from visits made to individual houses during the evaluation mission are presented in Appendix 7, from which it can be seen that routine maintenance did not appear to be being carried out in Tuvalu at the level required to ensure the long term sustainability of the systems.

4.3.2 PV System sizing in Tuvalu

As is described in Section 4.2.2 above, the methodology used by the original PV follow-up project team is described in detail in their Final Report of May 1995, and rather than attempting a critique of their approach, it was decided for the purposes of this evaluation to produce an independent estimate of the required system size, and then to compare this with the sizing which was actually adopted for the project. Our independent sizing estimates are shown below:

Estimated energy demand : Although many of the households visited no longer had their original lamps, our estimate for the required system size in Tuvalu is based on our understanding of what the users would like to have employed had TSECS provided the necessary appliances. On the basis shown in Table 4.8, we therefore estimated the useful energy demand from the PV systems installed in Tuvalu at 267 Wh/day (see below), which is slightly higher than the figure of 224 Wh/day, which was estimated by the original project team.

Table 4.8 Estimated energy demand in Tuvalu

Energy demand	Wh/day
3 lamps @ 11 W operating for 6 hours	198
1 radio @ 16W operating for 4 hours	64
1 night light @ 0.5 W operating for 10 hours	5
TOTAL	**267**

Estimated PV system losses : There are many possible causes of energy losses in a PV system. These are discussed in Section 4.2.2 and summarised in Table 4.3, where it can be seen that the predicted Performance Ratio for the PV follow-up systems is 53%.

Estimated PV energy delivered : Based on the estimated Performance Ratio of 53%, the energy delivered by one of the PV follow-up systems in Tuvalu, may be estimated at ~ 270 Wh/day, as shown below.

Table 4.9 Estimate of PV energy delivered in Tuvalu

Nominal PV array rating	= 100 Wp
Daily average solar irradiation (see Appendix 8)	= 5.1 kWh / m^2.day
Nominal PV array output (rating x irradiation)	= 510 Wh / day
Performance Ratio	= 53 %
Delivered energy (nominal PV array output x Performance Ratio)	= **270 Wh / day**

Comparison with sizing by the original project team: The simplified sizing estimates shown above are broadly in agreement with those presented by the original project team in its Final Report of May 1995, and confirm that the design used in the PV follow-up project may have a modest margin of safety when the systems are new, since some of the predicted losses occur with ageing. However, these systems are designed to last for 20 years, and the safety margin will undoubtedly reduce as the systems age. Also, it is to be expected that a user's demand for electricity will increase during the lifetime of their PV system, for example if they purchase other electrical appliances such as a CB radio. Finally, it is good practice to provide some over-sizing of the PV array because this facilitates overcharging of the battery, ensuring good mixing of the electrolyte which helps to minimise corrosion of the plates and prolong battery life - especially after several days of bad weather.

The sizing of the batteries for these systems is broadly consistent with the analysis presented above. The Oldham batteries have a nominal capacity rating of 100 Ah (C_{10}), which at 12V corresponds to a capacity of 1,200 Wh, or approximately 4 times the daily energy demand. In order to ensure a good working life, it is normally recommended that batteries should not be cycled through more than 20 - 25 % of their nominal capacity, so this industry guideline was followed in the design used for the PV follow-up projects. Similarly, it is recommended that the battery capacity should be sufficient to accommodate typical periods of bad weather (typical periods depend on the local climate). The climate in Tuvalu has more extended periods without sunny days than Kiribati, and it also has an average level of solar irradiation which is about 10% lower than Kiribati. So, the same PV array in Tuvalu will be able to supply less energy per day than in Kiribati, but the battery capacity should be at least as big as in Kiribati, in order to provide for longer periods without sun. In practice the battery size of about 100 Ah for the standard systems in Tuvalu appears to be adequate, and is typically more than about 4 times the daily energy demand.

4.3.3 Reliability of equipment installed in Tuvalu

Unfortunately, because of bad record keeping by the TSECS , it proved impossible to determine how many systems were actually still working in Tuvalu. Based on the sample of PV systems inspected during our mission, it seems likely that 25% or more of the systems in Tuvalu may no longer be working at all, and of those that are working, many may not be providing a full service.
Nevertheless, current users are generally happy with their PV lighting and those without it want it. TSECS keeps a waiting list of up to 20 households on each island who have paid a deposit of 50 AUD to obtain a PV system as soon as one becomes available. All of the PV systems installed under the PV follow-up project operate at 12 Vdc, without inverters .

The condition and reliability of the **PV modules** (Siemens) was found to be excellent, with no evidence of failed modules amongst those supplied in the PV follow-up project, though some were mounted too flat for rain water washing to be effective. The design lifetime of the PV modules is more than 20 years, and the evidence from the mission does not suggest otherwise. However, some of the PV modules, which had been installed in the first phase of the PREP were not in such good condition. For example, moisture ingress in some early BP modules had reduced their open circuit voltage to less than 8 Voc, and several ARCO M61 modules showed heavy discoloration, probably due to u-v degradation of the EVA encapsulant.

The **batteries** (Oldham) which were supplied in the PV follow-up project were generally in a fair condition, except where they had been abused or where controllers were not working properly. It is well known that battery condition is strongly dependent on the quality of the maintenance received. In Tuvalu, the condition of the batteries after more than 4 years of operation suggested that the quality of the maintenance was variable. The design lifetime of this model of Oldham battery is 5 years, and the evidence from the mission suggests that only a few of the batteries in Tuvalu are likely to significantly exceed this. Other batteries have also been installed in Tuvalu, notably BP Solarbloc and Kobe car batteries, which were made in Fiji. The BP Solarbloc batteries are comparatively difficult to maintain, since it is not easy to see the level of electrolyte though their opaque casings, and some of them could only be opened with a screw driver or coin. Not surprisingly, these were generally not in very good condition, and appeared to have a shorter lifetime than the Oldham units. The car batteries were all in poor condition, and although costing 75% of the price of Oldham batteries, their lifetime appeared to be little more than about one year (compared to ~5 years for Oldham).

The SEC **controllers** were generally in good working order, though it was clear that the field technicians did not fully understand how they work. There had been little or no training of the TSECS technicians for several years and, as a result, they were largely unable to deal confidently with the special plug in the controller which permits "equalisation" charging of the battery. Their tool kits were also somewhat lacking and, although the General Manager carried out new hydrometers for them during our mission, these were of poor quality and one fell to pieces within less than three hours of use. The SEC controllers have a design life of ~8 years, and most of them appeared able to last that long. Some of the first generation of SEC controller boxes were difficult to open because of corrosion of the cover screws, but the circuitry inside was generally in good condition. A significant number of the systems still employed the original GIE Soler controllers, which continue to provide charge and discharge control, but have no facility for permitting equalisation charging of the battery.

The quality of the **cabling** in Tuvalu was mixed. The mission found many examples of connections that had been made using only twisted wires instead of screwed terminal blocks, and of cables which were longer than necessary - leading to unnecessary extra voltage drops. The terminal blocks used were also of rather low quality, with steel screws - instead of brass - which corroded easily.

The design life of the **light bulbs** (Philips) is 8000 hours, and many had already operated for >7000 hours. Quite a number therefore had already failed, as might be expected. The lifetime of the **light fittings and ballasts** which were installed during the PV follow-up project was said to be ~ 4 to 6 years, but a number of these had also failed. In view of the general lack of support from TSECS, some users had replaced their failed lighting units with either tail lights from motor cycles or with conventional 18 W tube lights, bought from the shops on the main island. Users seemed to be disappointed in the brightness of the night lights, which were designed to allow them to move around at night.

The reliability of the **vaccine refrigerators** was disappointing. Inadequate provision had been made for spare parts either in Funafuti or in the outer islands (i.e.: they did not follow WHO recommendations for spare parts - see Appendix 15), and there appeared to be very few local skills or practical experience in the repair / maintenance of PV refrigerators. Similarly, it seems that the **domestic refrigerators** from Solelec (Total Energie) had demonstrated relatively poor reliability though, because of the poor state of the TSECS record keeping, it was difficult to confirm this observation.

As might be expected, the main causes of **PV system failure** were abuse by users (lights left on all night, illegal connections of appliances such as high powered cassette radios or lights, etc), corrosion of cable connections, switches, and light fittings (due to salty air and high humidity conditions), shading by rapidly growing trees (eg: pawpaw), and inadequate maintenance by technicians who lacked the necessary training to properly carry out their duties.

4.3.4 Numbers of people trained and working in PV technology

TSECS has three full time staff in Funafuti and 7 field technicians (one in each of the outer islands). Other staff have been trained during and since the PV follow-up project was implemented, but due staff turnover, several had moved on to other jobs. As a result of the lack of staff continuity, combined with poor management, most of the technicians had not been sufficiently trained, and refresher training for long serving staff had also not been carried out for the last few years.

4.3.5 Total energy generated in Tuvalu

No monitoring of energy production was provided as part of the PV follow-up project. The energy output from a PV system depends on many variables, including the demand of the users, and can be estimated using the approach presented in Section 4.3.2, as follows :

Typical PV system rated at 100 Wp
Average daily solar irradiation (Appendix 8) = 5.1 kWh/m^2
Average daily energy delivered per system = 270 Wh / day
Total number of systems installed ~ 400 systems

Total energy delivered by the PV follow-up systems in Tuvalu
= 270 Wh/day x 400 systems
= **108 kWh/ day or 39,420 kWh / year.**

4.4 BENEFICIARIES

The whole community benefits from PV lighting systems and the provision of vaccine refrigeration. Men, women, the young and the old are all able to benefit from these amenities. Table 4.10 (below) summarises the main services provided by PV systems and shows who the main beneficiaries are for each.

The Table shows that old and young people benefit more or less equally, but that there is a slightly greater benefit to women than to men. This is mainly because the women do the cooking, tend to sick children, make handicrafts and prepare the night fishing catch. The men benefit particularly from PV lighting when they are preparing to go fishing at night, but when they are actually fishing they still need to take their kerosene pressure lamps with them to attract the fish.

No specific benefit targets were set at the beginning of the PV follow-up project, so it is a little difficult to say that the project has achieved the intended benefits. Nevertheless, if we look at the logical framework which has been constructed for this evaluation (see Appendix 3) and compare the observations and findings of the mission with the expected results, we can say with confidence that PV systems are meeting the framework objectives of contributing towards rural development and a better quality of life on the outer islands of both Kiribati and Tuvalu. In particular, the PV systems on the islands (including both those funded by the PV follow-up project and those funded by other donors) are contributing towards improved health, improved education, access to water, access to communications, entertainment, and leisure facilities. The one area where PV is not having as great an impact as expected is in the stimulation of new income generating activities and reducing poverty. This is mainly due to the isolation of the communities and their lack of access to markets, as well as the limited resources from which they can generate incomes, ie: fish, copra, and leaves or shells for handicrafts.

Table 4.10 Beneficiaries of Solar PV services

Services provided by PV	Main Beneficiaries			
	Men	Women	Children	Old People
PV lighting for:				
1. cooking (most cooking is done outside on open fires burning coconut husk, but when it is raining some less poor households use kerosene cookers indoors)		✓		
2. eating	✓	✓	✓	✓
3. reading	✓	✓	✓	✓
4. games/socialising	✓	✓	✓	✓
5. preparing to go fishing at night	✓			
6. preparing the night fishing catch (gutting, salting)		✓		
7. tending to sick children		✓		
8. dealing with own sickness	✓	✓		✓
9 making handicrafts at night		✓		
10. security lighting for shops	✓	✓		
11. night lights to allow movement around the house at night (reassurance for the old and young)			✓	✓
12. medical centre facilities in the evenings	✓	✓	✓	✓
13. Maneabas (public meeting halls) used for social activities and community meetings	✓	✓	✓	✓
14. Outside lighting for socialising, security, and movement between buildings	✓	✓	✓	✓
15. Port Lighting	✓	✓	✓	✓
PV Electricity for:				
Vaccine refrigeration – medical services			✓	
Radio/Cassette Players (News, culture, music)	✓	✓	✓	✓
CB Radio (Communications)	✓	✓		✓
Telephone	✓	✓		✓
Water pumping for schools			✓	
Computers/printers in schools			✓	
General Advantages of Solar PV are:				
• PV lighting is a very convenient source of light at the flick of a switch when you want it compared to: - Kerosene lanterns and pressure lamps which take time to light and are messy; - grid electricity which has limited hours of operation.	✓	✓		✓
• PV lighting gives a better quality and distribution (radius) of light;	✓	✓	✓	✓
• PV lighting is much safer compared to Kerosene lanterns/pressure lamps or mains voltage (240 Vac) electric lighting.			✓	
• PV is a more reliable source of light compared to grid and kerosene lighting, because these alternatives suffer from fuel shortages, also grids in these remote areas often suffer from outage due to storms or overload.	✓	✓	✓	✓
Sum of benefits /advantages	**16**	**19**	**15**	**15**

Note: the information in this table is derived from information gathered and discussions held during the evaluation mission to Kiribati and Tuvalu.

5. Impacts of the project

5.1 IMPACTS ON FUEL USE

5.1.1 Impact of PV systems on overall petroleum fuel consumption

The impact to date of the PV follow-up project on the overall consumption of fossil fuels in the two countries concerned and on their future dependency on fossil fuels is, of course, relatively small. In numerical terms, the impact can be estimated from the quantity of petroleum fuel that would otherwise be used by the families who now have PV systems, which is about 163 kl/year (see Section 6.2.1). When compared with the total petroleum fuel consumption by the two countries, which is about 11,500 kl per year, it can be seen that the fuel saved represents just over 1% of the total. Whilst this is clearly a relatively small fraction of total national petroleum consumption, it is important to remember that much of the petroleum fuel (approx 87% in Kiribati and about the same in Tuvalu) is used for transport and only about 13 % is used by households.

As a result of the PV follow-up project, 34% of the ~1160 outer island households in Tuvalu and 4% of the ~7,508 outer island households in the Gilbert Group of Kiribati have been fitted with PV systems. The estimated petroleum fuel saving from PV systems as a proportion of the petroleum consumption in the household sector (currently about 1500 kl for the two countries) is therefore much higher, at more than 10% of the total household petroleum fuel consumption.

These estimates are based on extremely imprecise data, and should be considered only as indicative of the overall impact achieved. However, they do suggest that there is potential for PV systems to play an important role in reducing present and future petroleum fuel consumption in the household sector, especially in the outer islands. This is because the efficiency of fuel use by households is very much lower on the outer islands than on the main islands where large scale power generation is able to offer household lighting for much lower levels of petroleum fuel consumption than is possible with kerosene lamps and small generators.

In summary, it is clear that the PV follow-up project has achieved a significant reduction in the use of kerosene on the outer islands, and furthermore has demonstrated the potential for far greater reductions in the dependency of the outer island households on fossil fuels in the future.

5.1.2 Impact of PV systems on how energy is used by rural households

The development of rural communities, especially those on remote islands, is naturally a very slow and difficult process and, consequently, it is hardly surprising that the energy needs of the communities on the outer islands of Kiribati and Tuvalu have changed very little since the implementation of the PV follow-up project.

Nevertheless, the information gathered during the evaluation mission suggests that some changes in household energy uses are taking place in the outer islands, and more changes can be expected in the future, as economic and social development continues to advance. Our findings concerning these trends in energy use are summarised in Table 5.1 (below).

Table 5.1 Household energy needs and uses before PV follow-up and now

	Sources of energy used/available	
Energy need / use of energy	**Before the PV follow-up**	**Now**
Heat for Cooking	Biomass (coconut husks)	Biomass (coconut husks) and some kerosene stoves
Lighting	Kerosene lantern and pressure lamp	Kerosene lantern, pressure lamp and electric light (PV, diesel

		generator or grid)
Mechanical power for water pumping	By hand	By hand and electric pump (PV, diesel or grid)
Electricity for refrigeration/freezing	none	PV, diesel generator, grid or LPG
Electricity for CB Radio, telephone	Some earlier PV systems	PV or grid
Electricity for radio/cassette	Dry cell batteries	Dry cell batteries, PV or grid
Electricity for TV/Video, Film projector	None	Diesel generator or grid
Mechanical power for fan	By hand	By hand, electric fan (grid)
Mechanical power for washing clothes	By hand	By hand, washing machine (diesel generator or grid)
Mechanical power for transport - motor bike, truck, or outboard motor	Petrol, Diesel	Petrol, Diesel

It can be seen from Table 5.1 that PV power is helping to replace the use of kerosene in lanterns and pressure lamps, and the use of dry cell batteries in radios and cassette recorders. These are undoubtedly the main applications for which PV is able to make a significant impact in the outer islands in the short and medium term.

PV electricity is also providing power to replace human effort in water pumping (particularly in schools) and services which were not available previously e.g. CB radio, telephone, refrigeration/freezing. Where they are available and affordable, diesel generators and grid electricity are beginning to provide power for more expensive appliances such as washing machines, TV/Videos, film projectors, electric fans, and refrigerators/freezers. However, few households on the outer islands can afford to buy or rent such appliances, so their usage is still relatively rare. Energy use in transport is increasing, but very few households can afford to buy motor bikes or outboard motors, and in any event PV will not have an impact on the use of transport fuels.

The PV follow-up project did not provide PV systems in schools, but there is a demand for PV lighting for dormitories in the secondary schools to improve conditions for reading and study in the evenings.

Tourism is negligible in the outer islands of both Kiribati and Tuvalu, but PV lighting systems are used by the small shops for trading in the evenings and for security lighting at night. The Island Council guest houses had PV lighting in Nonouti and North Tarawa, and small diesel grids for the Island Council buildings in Marakei, Vaitupu and Nukufetau (but it was not working there).

There is no TV yet in the outer islands of either Kiribati or Tuvalu, but PV lighting is used for evening meetings, playing games (eg: cards), and reading. There is a growing demand for larger PV systems to power home videos. Satellite TV is now available in Funafuti, so it may not be long before TV becomes available in the outer islands of Tuvalu.

5.2 ENVIRONMENTAL IMPACTS

Visual impacts in the village communities – the PV systems blend in very well with the traditional building materials and style of house on the outer islands. Indeed, this is so much the case that it is actually rather difficult to spot the PV systems unless you look carefully. The visual intrusion is therefore considered to be insignificant.

Damage caused by dumping of old or leaking batteries – at present, not many of the PV system batteries have been replaced, so the effects of battery disposal are not yet evident. However, many of the PV batteries are coming up to the end of their useful life and will need replacing soon. It is therefore important to address the issue of battery disposal now so that measures can be taken to ensure their safe disposal/recycling. When planning for battery disposal the following points should be taken into consideration:

- Some car and truck batteries are already having to be disposed of on the main islands in each country, and good environmental practices should apply to all lead acid batteries.
- Lead from car and truck batteries can sometimes be reused as weights for fishing nets
- Boat owners may be unwilling to transport old batteries for fear of leakage of acid onto their decks, which could damage the boat and contaminate other goods being carried, especially food products.
- Small spillages of acid are not too damaging in the outer islands which consist largely of coral sand, because the coral is alkaline and will neutralise the acid. However, it is highly undesirable to introduce lead into the ground water (even in Tuvalu where little ground water is used for drinking).
- The nearest manufacturer of car batteries to Kiribati and Tuvalu is in Fiji, and the nearest manufacturer of deep discharge batteries is in Australia. Therefore, there is not likely to be anywhere closer than Fiji that is prepared to recycle old batteries.
- At present the disposal of dry cell batteries used in torches and radio/cassette machines is becoming an environmental problem. Used dry cell batteries are currently being discarded in an uncontrolled manner, and are frequently just thrown onto the ground.

Savings in CO_2 emissions – one of the increasingly important reasons why international aid is used to support the introduction of renewable energy is to reduce the impact of fossil fuel emissions on the global environment. As discussed in Section 4.1.2, the overall CO_2 savings arising as a result of the PV follow-up project have been estimated at about 408 tons per year, based on data provided by the users.

Potential savings in other emissions - The existing PV systems on the outer islands are mainly replacing the use of kerosene lights and dry cell batteries in radio/cassette machines, and are too small to replace the mobile diesel generators which are currently used for TV/Videos, film projectors or other high powered appliances. However, small distributed PV systems could easily replace the use of the existing diesel based mini-grids for lighting in local government buildings, and larger PV systems could be used for lighting in the larger community buildings such as maneabas (in Kiribati) or falekaupule (in Tuvalu). The replacement of such diesel generators by PV systems would, in addition to CO_2 mitigation, produce savings in local emissions of waste oil, noise, and other exhaust gases.

5.3 HEALTH IMPACTS

The information gathered during the evaluation mission from discussions with local health workers suggests that they are managing to control most of the well known serious diseases (whooping cough, eye infections, etc), and that the most common illnesses on the outer islands today are dysentery, diabetes, stress-related illnesses (heart disease, high blood pressure etc), and infected cuts and sores.

One of the reasons for their success is that professionally managed health centres are operated on each island, and these are each fitted with PV lighting which permits the sick to be tended at night, and PV vaccine refrigerators for the clean and proper storage of medicines.

5.4 IMPACT ON AVAILABLE SKILLS IN PV TECHNOLOGY

Training and capacity building formed an important element of the PV follow-up project. All of the staff in SEC and TSECS were trained at the start of the project, and their training was reinforced in the subsequent regional training and capacity building project, which was managed by GTZ / BTG. Some of those staff who were trained during the PV follow-up and other PV projects in the region have now left the companies concerned, but their training is almost certain to be of use to the region in some way in the future. Until now, no new PV businesses have been created as a result of the PV follow-up project, so the main focus for PV skills in the two countries remains in SEC and TSECS.

Three broad levels of skill in PV technology appear to have been created by the PV companies, with a large contribution from the PV follow-up project, as follows:

Field technician
Field technicians generally have no formal qualifications, and cannot be expected to fully understand the principles behind PV system design. They must be responsible and respected members of their local community who can be relied upon to organise the collection of fees and to maintain the systems, ie: clean them, top up the batteries, replace light bulbs and repair broken wires, etc. They must also be able to report reliably on the status of their systems and of their fee collections to head office on a monthly basis, and to manage local stocks of spare parts. However, they cannot be expected to trouble shoot when complex electrical problems occur.

In Kiribati, field technician skills have been passed on to new recruits and existing field technicians have received refresher training through the internal training scheme operated by the senior staff of SEC. The current levels of field technician skills in Kiribati are therefore relatively good, and SEC currently has 5, one on each of Nonouti, Marakei and Abemama, and two on North Tarawa. In contrast, the high staff turnover and recent lack of funds at TSECS has resulted in 4 of the 7 field technicians in Tuvalu not having been fully trained.

Senior technician
Each solar company needs one or two senior technicians who can deal with more complex electrical problems when they arise. Senior technicians are expected to be based in the head office and to visit the field technicians on a regular basis in order to help them to deal with technical problems. They must fully understand the operation of the PV systems and their individual components, and also be able to review the technical information which is sent by the field technicians to the head office each month.

The ***local manufacture*** of PV systems controllers and dc/dc converters has also been carried out to date in SEC by staff who have been trained to senior technician level. These manufacturing skills combined with the business skills of the General Manager could provide an important basis for future export earnings, and further development of these skills should not be overlooked in the future.

SEC currently has only one senior technician (Teikona), but the General Manager (Terubentau) is also fully qualified to senior technician level, and beyond. In TSECS, both the General Manager (Timaio) and the Project Officer (Kapuafe) have been trained to senior technician level, but the Senior Technician (Ioshua) is newly appointed, and requires further training before he can fully carry out his role.

Now that the PV systems which were installed through the PV follow-up project have been working for more than 4 years, there is a growing need for advanced "trouble shooting" skills amongst the senior technicians. During the evaluation mission, it became clear that the existing senior technicians and their General Managers lacked these trouble shooting skills, and would greatly benefit from some more advanced training on this topic. Such training would undoubtedly best be carried out in the field, and as far as possible on-the-job.

PV Utility Manager
The management of a PV Utility service involves a number of business management skills, including stock control and international procurement, as well as the normal business management skills associated with staffing and finance.

Much of the responsibility for these tasks currently lies with the General Managers though, in the case of SEC, support is available from the rest of the head office management team. Nevertheless, on-going external management training and guidance at this level in SEC is likely to be required for several years to come, mainly because of the isolated location from which the business has to operate.

In TSECS, the Acting General Manager has been trained as a senior technician, but lacks both the training and experience required to work effectively at an executive level. In view of the challenges which currently face

TSECS in terms of the need to raise international financing, to refurbish the bulk of their systems over the next one to two years, and to completely restructure the organisation, there is a clear and urgent need for a more experienced Executive Manager to lead TSECS into the next millennium.

5.5 IMPACTS ON LINKED AND COMPETING SECTORS

5.5.1 Linked infrastructures

The main infrastructures that are needed to support the household PV lighting systems in Kiribati and Tuvalu are provided through the PV Utility services, which are operated by the PV companies, but there are some important ***linked infra structures*** which also need to be put in place, and which are currently working with differing levels of effectiveness as follows :

- ***Replacement light bulbs*** – In Tuvalu, bulbs are supplied freely by TSECS when they have them, but for most of the time they are not available (due to TSECS financial problems). In Kiribati, bulbs are in principle available for sale from the SEC field technicians, but the sales are not very effectively promoted. Better co-ordinated light bulb sales either through local shops or through the field technicians is needed.
- ***Schemes for collecting old batteries for recycling*** – no organised recycling schemes are yet in place, other than traditional practices of using old discarded items.
- ***Training of medical staff in the use of PV powered vaccine refrigerators*** **-** medical staff turnover in the outer island medical centres is relatively high and many are not trained in how to use a PV refrigerator before being put in charge of a medical centre which has one.
- ***Locally stored spare parts for medical refrigerators*** **-** No spares appear to be held on the outer islands for these vital pieces of medical equipment. There are WHO guidelines on what spare parts and what routine maintenance should be carried out for each type of vaccine refrigerator (see appendix 15). These should be interpreted for use in the outer islands and followed more closely in future.
- ***Banking of monthly fees*** **-** the Banking of the fees collected by the field technicians on a monthly basis appears to work well in both Kiribati and Tuvalu.

5.5.2 Competing sectors

At the present time, the main competitors for PV household lighting are kerosene and dry cell batteries. The supplies to the outer islands of both of these competing energy sources are unreliable, and neither is able to provide the quality of lighting which is offered by the PV systems. Moreover, batteries are much more expensive than PV lighting systems and kerosene is much less convenient to use.

Fortunately, no significant ***negative impacts*** such as losses of existing jobs or reduced profitability of existing businesses have resulted from the introduction of PV systems in the outer islands to date. This is mainly because the suppliers of liquid fuels already have problems in transporting their fuels to the outer islands and would find it difficult to increase their deliveries without changing the existing transport infrastructure. Dry cell batteries are sold by the local shops who stock a wide range of products, and a small reduction in the sales of batteries does not significantly affect their profitability.

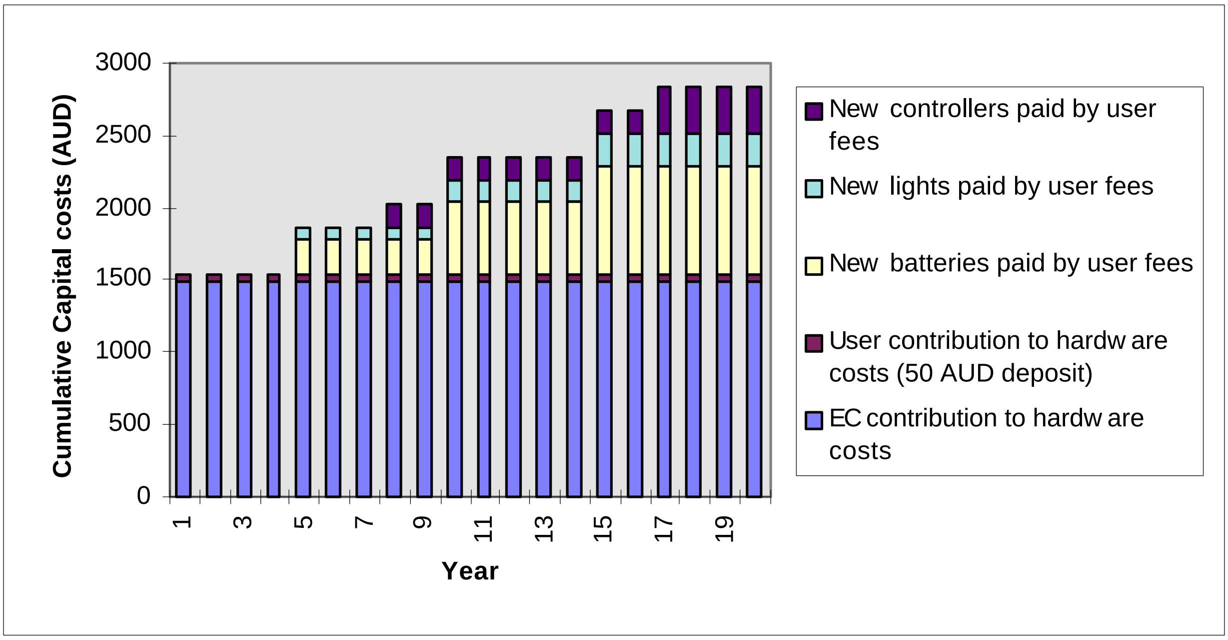
6. Financial and Economic Analyses

6.1 FINANCIAL ANALYSIS

6.1.1 Costs of PV electricity services

The financial analysis presented here is based on the investment and operating expenses which are seen by the rural PV Utility service providers (SEC and TSECS) and the users. In the case of Kiribati and Tuvalu, most of the initial capital costs of purchasing and installing the PV systems were paid by the EC in the form of donor aid. A contribution of 50 AUD towards the initial costs was paid by the users in the form of a deposit. The contribution by the EC represented about 50% of the capital costs for the first 20 year life cycle of the systems (see Figure 6.1), and the rest is paid by the users through the deposit and monthly fees of ~10 AUD.

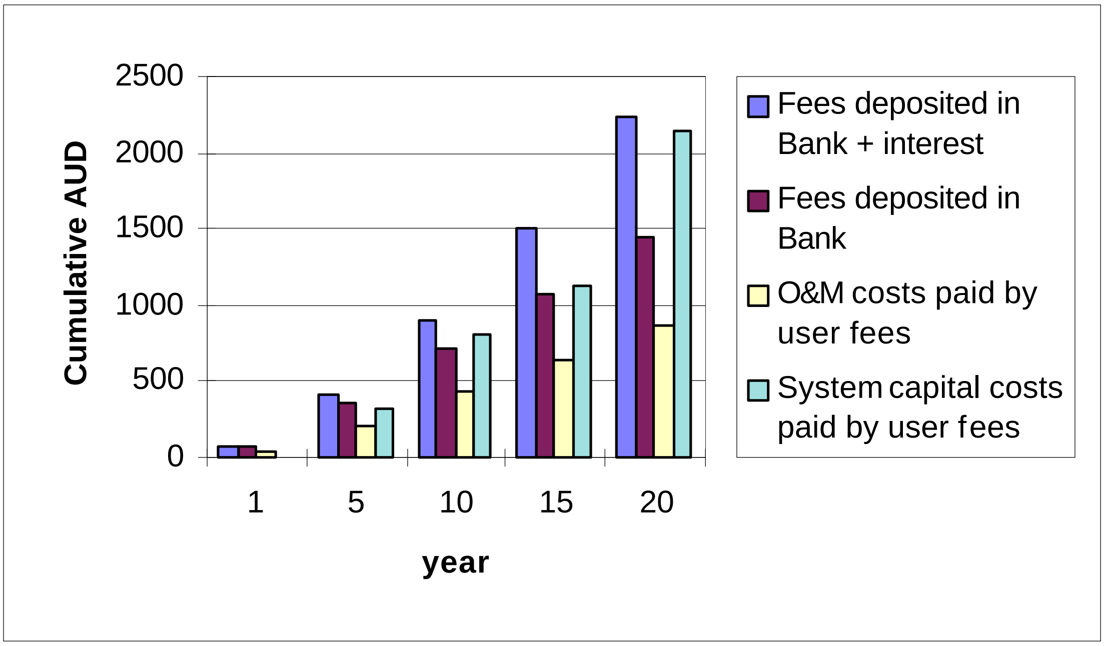
Figure 6.1 Capital costs of a PV system in a PV Utility scheme of 1000 systems over a 20 year life cycle



Once the systems have been installed, then ***no further subsidies are needed***. The full operating and maintenance costs of the PV systems are also paid by the users out of their monthly fees of 10 AUD. It is therefore on the basis of these O&M and component replacement costs (plus the down payment) that comparisons are made locally with alternative ways of providing the required services.

An important feature of the PV Utility business is the role played by the local Bank. The monthly fees, less the operating and maintenance charges, are paid directly into a local interest earning account, and the interest builds up over the system life cycle. As a result, the monthly fees can be made more affordable for the users, since the interest can be used as a contribution towards the costs of replacement PV system components (see Figure 6.2).

Figure 6.2 PV Utility fees and costs



The benefits derived from the PV electricity services are described in Chapter 4. However, when comparing the costs of PV electricity services with the alternatives discussed below, it is important to note that PV electricity offers substantial advantages in terms of 24 hour availability, independence of liquid fuel supplies (which are unreliable in the outer islands), low environmental impacts, high reliability and very low risks of injury to users (including children and the elderly).

As part of the training carried out during the PV follow-up project, an EXCEL spreadsheet was developed for estimating the fees which need to be charged by SEC and TSECS to cover the costs of providing their rural PV Utility services, and this spreadsheet is still in use in the region. The spreadsheet has been investigated as part of this evaluation, and some minor modifications suggested to its developers. However, in general terms it was found to be a useful way of analysing the investment and operating costs involved, and it seems sensible to use it again here so that those who are already familiar with it can quickly grasp the comments which follow.

Example printouts of the spreadsheet for 500 and 1000 systems in Kiribati are presented in Appendix 9, showing the costs of each PV system component and the replacement costs which need to be paid each month in Australian dollars (AUD). (note: 1 AUD $\simeq$ 0.6 Euro).

The analyses given in the spreadsheets show that the monthly fees needed to cover the costs of the PV Utility service in Kiribati in 1998 vary between about 10 and 13 AUD/month, for a monthly energy delivery of up to 300 Wh/day or 9.2 kWh / month per household. The required fees depend on the number of PV systems which are being managed by the PV Utility, and whether or not a dc/dc converter is installed. They correspond to delivered PV electricity costs of between 1.1 and 1.4 AUD/kWh (0.66 and 0.84 Euro/kWh).

The spreadsheets for Kiribati shown in Appendix 9 employ the following basic assumptions:

1. Fees are paid on a monthly basis by the users, and the money is deposited immediately by the PV Utility in an interest bearing account.
2. The effective interest earned from the deposited fees is estimated in advance and used to reduce the size of the fees which need to be paid by the users.
   ie:
   fees paid + interest earned = cash needed to replace components at end of useful life
   + cash needed to provide PV Utility services
3. The effective interest rate (actual interest rate less the relevant rate of inflation) is estimated taking into account historical experience in the Pacific, where in recent years the interest bearing accounts of SEC have earned between 5% and 6 %, and inflation of the PV system components has been very low and even negative. An effective rate of 4% therefore seems to be reasonable / possibly conservative.
4. SEC salaries and staffing levels are presented at the rates applicable for 1998.
5. For the case of 500 systems, the other basic operating and maintenance costs used in the Final Report of the PV follow-up project in 1995 have not been changed since they were presented at that time for 500 systems.
6. For the case of 1000 systems, it has been assumed that senior technician and technician inputs and associated travel and operating costs, as well as some of the indirect costs and spare parts costs, would be approximately double those estimated in 1995 for 500 systems.

Until now, the fees in Kiribati have been set at 9 AUD for systems without a dc/dc converter and 10 AUD where a dc/dc converter is provided. From this it is clear that some of the costs of the PV Utility services in Kiribati have been cross subsidised by SEC from profits earned from other PV project work. This is essentially because the fees have been set as a compromise between the real costs and the price which the rural households can afford. Recognising that the real costs will fall when more PV systems have been installed, discussions are on-going concerning an increase in the fees in Kiribati in the future. During the evaluation mission, it seemed likely that some increase in fees would be implemented in the future, in order to ensure that SEC could maintain the quality of its services, whilst it awaited further donor funds to increase the numbers of systems installed.

In Tuvalu, where TSECS have had problems managing their finances, the fees have been set significantly lower (~7 AUD/month) by the Management Committee. It is clear that the fees must be increased in Tuvalu, but this is unlikely to happen until TSECS is re-structured.

The spreadsheets also show the fees which would need to be paid if PV systems were purchased independently of donor aid and were financed using loans. Monthly fees are shown for a range of loan interest rates, for example ~20 AUD / month for a very soft loan at 0% interest rate and ~31 AUD / month for a more commercial interest rate of 12 %. From this it can be seen that the fees required to pay off a loan are more than twice those which are currently being paid, and our interviews with the householders on the outer islands indicated that such fees would be too high for many of the rural households to afford. It follows that loan based PV electrification in Kiribati and Tuvalu is unlikely to meet the development objective of providing affordable lighting and low power electricity services to the majority of the rural population.

The initial down payment of 50 AUD represents a significant sum for a typical rural household, whose monthly income lies between 150 and 300 AUD per month, and who spends most of this on essentials like food, clothing and education of their children. The main purpose of the down payment is to demonstrate commitment to the payment of the monthly fee, and not to purchase the PV system itself, since all of the PV systems remain the property of the PV Utility. In this sense, the down payment is comparable to the connection fee charged by a conventional grid utility, and should be set at a level which is affordable by as wide a range of income groups as possible. Since the down payment represents less than 2% of the costs paid by the users over the 20 year lifetime of the PV systems, it has not been taken into account when estimating the costs of the PV electricity.

6.1.2 Costs of small diesel generators with local low voltage networks

Small low voltage networks have been installed to provide power to a small number of official buildings in the outer islands of Kiribati, and a larger local network has recently been installed in Vaitupu in Tuvalu. The diesel schemes in Kiribati typically operate for only 4-5 hours per night, and their full costs are rather difficult to establish, because in the majority of cases the generators have been obtained second hand or from donors or from completed aid projects. However, details were obtained of the scheme in Vaitupu as explained below.

The diesel scheme in Vaitupu, Tuvalu : This was built by the Island Council in 1996, using two diesel generators (one of 75 kW and one of 45 kW) which were donated to the Island Council by Dai Nippon in exchange for access to land required for a fish market project. The system supplies ~120 households and uses approx 10 drums of fuel per month (2000 litres), at a cost of 1,700 AUD per month (170 AUD/drum). The estimated cost of operating the scheme is 2800 - 3000 AUD/month, including salaries for the 4 staff who manage it and the spare parts for the generators. This would correspond to about 25 AUD/month per household. The householders mainly pay on a flat rate basis depending on the appliances which they use. Two of the householders that we visited said that they were paying 30 AUD/month for their grid electricity (to power lights, refrigerator, video and washing machine) and one was paying only 10 AUD/month (lighting only). The island council claimed that the scheme was currently losing more than 200 AUD/month, even after reducing the operating hours to only 6am to noon in the morning and 6pm to 10pm at night. Hence, in practice, the diesel powered scheme (which was losing money) was charging rural users a fee of 10 AUD/month for lighting which was only available for 4 hours in the evening. Those users, whom we met, were prepared to pay for solar lighting in addition to the diesel in order to have access to lighting throughout the night if they needed it.

Small petrol and diesel generators are used to provide local supplies of electricity in both Kiribati and Tuvalu, but these are run for as long as the electricity is needed, rather than to charge a battery. Typical uses are to provide power for a video, film projector or photocopier, or to fill a water cistern using a portable pump. A very small number of users employ small generators to provide power for lighting or refrigerators, and these were only to be found in local shops or community facilities.

Small Yamaha generators in Kiribati : The capital costs of the 700W Yamaha generators which were being used in Kiribati were around 1000 to 1200 AUD, which is between 2/3 and 3/4 of the capital cost of a PV system, so it was only organisations (such as schools) or rich families, who had an external income from seamen or from a business on the main island that could afford to buy them. If such a generator were to have a lifetime of 10 years, then its capital costs alone would correspond to ~10 AUD per month. The operating costs of these generators were also relatively high. For example, if the 700W Yamaha were operated for 5 hours per night, consuming (say) 0.46 litres per kWh of fuel with a cost of 70 AUD cents per litre (Kiribati) or 85 AUD cents per litre (Tuvalu), then the fuel cost would be around 1 AUD per night or 30 AUD per month. Clearly, it would be much more expensive to use such a generator for lighting than to use a PV system.

6.1.3 **Village electrification** (medium size diesel, medium voltage distribution)

Examples of such schemes are only available on the main islands in Kiribati and Tuvalu. The costs of the power are those which apply to the main island grids, namely

	Commercial rate AUD / kWh	Domestic rate AUD / kWh	Average rate AUD / kWh
Kiribati	0.39	0.35	0.38
Tuvalu	0.34	0.34	0.34

The grid based schemes on the main islands provide greater benefits to their users than the small diesel generator schemes on the outer islands because the users have access to much higher power levels with reasonably good reliability and a 24 hour service. It is therefore not surprising that PV lighting systems are generally not in use on the main islands (except in areas away from the diesel powered electricity network)

6.1.4 Grid extension

The prices of electricity supplied to users via a grid extension are the same as those for the main grids, as shown above. The hours of service are also equivalent, which in the case of extensions to the main island grids of Kiribati and Tuvalu would be 24 hours.

The best example of a recent grid extension is that of the extension from Buota to Nabeina on North Tarawa, Kiribati. Here, a 10 km extension was built on the assumption that the level of demand would be higher than it has turned out to be. In fact, most of the households which have been connected use only lighting and pay less than 5 AUD per month. Local reports obtained during the evaluation mission suggested that the last 3 km of this extension were no longer working because a transformer had failed and the costs of replacing it could not be justified for such a low energy demand / monthly income. This experience is just another example suggesting that whilst the price of electricity from grid extensions and the potential access to high power may be attractive to users, the operating costs and overall economics are likely to be such that they are not commercially / economically viable from a supplier's point of view on the tiny outer islands of the Pacific.

6.1.5 Battery (12V) charging station (diesel based)

No examples of a diesel based battery charging station were found during the evaluation mission, though the SEC technicians were providing limited battery charging services using spare PV modules in Kiribati. Small petrol and diesel generators were used to provide local supplies of electricity, but they were run only for as long as the electricity was needed, rather than to charge a battery, eg: to provide power for a video, film projector or photocopier, or to fill a water cistern using a portable pump.

Centralised battery charging services could theoretically permit isolated users to have battery powered dc lighting without the need for individual PV generators. However, such a scheme would of course be totally dependent on liquid fuel supplies, which are known to be unreliable on the outer islands, so one of the key disadvantages of kerosene lighting would not be removed by such a solution. In the absence of local grid power, the costs of operating such a scheme would depend largely on the size of the generator used and the number of customers involved, as well as on the types and quality of the batteries employed. Until now, it seems, nobody has been willing or able to establish such a scheme at a sufficiently low cost to outweigh the disadvantages associated with the unreliability of liquid fuel supplies.

The lack of local transport services would also militate against such a scheme - only the more wealthy households have a bicycle or hand cart which might be used to transport the batteries to a charging centre. (Note: such schemes work in some parts of Africa, where trucks are more common, and where the more wealthy households are prepared to transport batteries for recharging - usually from a local grid system.)

6.1.6 Dry cell charging station (solar powered)

Rechargeable NiCd batteries are widely available on the international market for use in radios, cassette players and torches, but none was seen in the outer islands of either Kiribati of Tuvalu. Many NiCd batteries look very similar to classical dry cells, but are typically much more expensive to buy, and their disposal needs to be more carefully controlled from an environmental point of view, especially because of the cadmium involved. Solar powered NiCd battery chargers have been developed for use in rural areas, for example one was developed for use in the PRS project in the SAHEL. However, they have not been very successful, probably because untrained users can easily confuse the NiCd batteries with classical dry cells. In the light of the environmental risks, their relatively high costs, and the lack of success with such schemes elsewhere, it is perhaps not surprising that their use has not been encouraged in the Pacific.

In contrast, dry cells are widely available on the islands for torches, radios and music cassette players. Two main types are used, namely the lower cost (green) cells (size D) at about 80 AUD cents and the higher quality (red) cells (size D) at about 1 AUD. Prices vary from island to island, and in some places it appeared that the two qualities were sold for the same price - availability being the key issue.

It proved to be quite difficult to establish how much households were paying per month for dry cell batteries, even in households without solar lighting, because the users themselves kept no records (mental or written) of such expenditure. However, anecdotal evidence suggested that some households might be spending 5 AUD per month or more on dry cells to operate torches for moving around at night, and for night fishing. This is of course in no way comparable to the full lighting service provided by the PV systems.

Exhausted batteries could be seen lying on the ground outside many houses, suggesting that safe disposal has not yet been properly addressed. The numbers of batteries on the ground were not yet large enough to cause major concern, but if the trend continues, then environmental pollution will clearly become an increasing problem in the future, and is merely symptomatic of a larger waste disposal problem.

6.1.7 Kerosene wick lanterns and pressure lamps

Kerosene is the main source of lighting in households without PV lighting systems, and both wick lanterns and pressure lamps are used. Pressure lamps typically cost around 80 AUD and consume around 0.5 litres per night. Wick lanterns are cheaper, typically costing around 20 AUD and consuming only about 1 litre per week.

The operating costs of these devices clearly depend strongly on their users, but can be estimated as follows:

Wick lantern :
Capital costs spread over 10 years = 0.17 AUD / month
Fuel costs per light = 2.16 AUD / month (Kiribati), or = 3 AUD / month (Tuvalu)
Total per light = 2.33 AUD / month (Kiribati), or = 3.17 AUD / month (Tuvalu)
Total (3 lights) = 7 AUD / month (Kiribati), or = 9.5 AUD / month (Tuvalu)

Pressure lamp :
Capital costs spread over 10 years = 0.67 AUD / month
Fuel costs = 8.37 AUD / month (Kiribati), or = 11.25 AUD / month (Tuvalu)
Total per light = 9.04 AUD / month (Kiribati), or = 11.92 AUD / month (Tuvalu)

These cost estimates need to be treated with caution, because few (if any) households actually operate three wick lamps in parallel on a regular basis, and if a family has a pressure lamp (very few households have more than one pressure lamp), then it is likely to be used also for fishing at night. Hence, it is quite common for a household to use a mixture of one pressure lamp with one or more wick lanterns.

The general opinion of the users interviewed during the evaluation mission was that the provision of 3 PV lights is more or less cost competitive with kerosene lighting if it can be achieved for costs which are not substantially greater than 10 -12 AUD / month. They also drew attention to three key benefits of PV lighting over kerosene, namely

1. Convenience - available at the flick of a switch rather than having to light a lantern in the dark
2. Reliability - not dependent on unreliable supplies of liquid fuels
3. Safety - children can turn on the light without risks of burning themselves or setting fire to the house

6.1.8 LPG lamps

LPG has only started to emerge as a significant energy source in the main islands of Kiribati and Tuvalu during the last few years, and consequently few appliances are available for its use.. It is not yet commercially available in the outer islands of Kiribati, and in Tuvalu it is only available to a few wealthy individuals who make their own arrangements for its transport. It is sold in either 13 kg or 50 kg cylinders which are supplied from Fiji, but distribution is still on such a small scale that the prices remain relatively high. The main application for LPG in the near future will continue to be for cooking on the main islands.

Even if LPG were to be promoted more strongly in the outer islands, it would still suffer from all of the problems associated with kerosene, namely inconvenience, poor reliability of supplies due to transport difficulties in the outer islands, and safety. Its main advantage over kerosene is that it is slightly cleaner and easier to handle.

Prices for LPG in Fiji were around 1.6 AUD/kg, but far higher prices were quoted in Kiribati (up to 3 AUD/kg) and in Tuvalu (up to 2.5 AUD/kg). The prices in the outer islands of Kiribati and Tuvalu would need to fall to around those in Fiji before LPG would be cost competitive with kerosene for lighting. Higher LPG prices may be commercially viable for cooking in the main islands of Kiribati and Tuvalu for reasons of convenience - provided that reliability of supplies can be guaranteed.

6.2 ECONOMIC ANALYSIS

From the viewpoint of the Governments of Kiribati and Tuvalu, the economic importance of the PV follow-up project may be judged in terms of its impacts on the national balance of payments and on development in the outer islands. Perhaps equally important are the extent to which it has helped to encourage families to remain on the outer islands rather than to migrate to the main islands, and the number of permanent jobs which it has created.

6.2.1 Reductions in imported fuel costs

PV lighting has replaced the use of kerosene lighting and, at the same time, has improved the quality of the lighting provided. It has also provided the rural families with access to radio and music at affordable costs.

In Kiribati, it might be estimated that the lighting fuel saved would be around 20 litres per household per month for ~300 households, which is equivalent to an imported oil bill of about 40,000 AUD per year. In Tuvalu, the equivalent savings from ~380 households would be about 50,000 AUD per year. Hence, the total fuel import savings might be estimated at ~90,000 AUD per year for the two countries. However, this does not include the avoided costs of transporting the fuels to the outer islands, which are very difficult to estimate, and it takes no account of the improved quality of life which the PV lighting provides over that of kerosene lighting.

An important question to be addressed by the Governments of the two countries is whether or not to install grid power on their outer islands. It is not feasible to present an in depth study of this subject here, but it is clear from the experiences in Vaitupu and from the Nabiena grid extension on North Tarawa that the level of demand for electricity from these low density, poor rural communities is not sufficient to permit the establishment of a commercially viable electricity grid which operates on a 24 hour basis. Hence, from a National point of view, such a venture would inevitably require substantial financial subsidies on a long term basis.

6.2.2 Development of the outer islands

The provision of improved lighting and access to radio undoubtedly improves the quality of life on the outer islands, and is important to the future of the communities concerned. The benefits are particularly noticeable in the medical centres, where care can now be provided more effectively during the night, and in the shops and local meeting halls where people gather after dark. The benefits of these developments can be seen at a National level in terms of the social cohesion of the communities concerned and their ability to support themselves. However, it is not feasible to try to put monetary values to these effects.

6.2.3 Migration from the outer islands to the main islands

One of the key problems for the governments of both Kiribati and Tuvalu is overcrowding on their main islands. In Kiribati, South Tarawa is very congested, and this has led to major problems with water supplies and sanitation. In Tuvalu, there are similar problems with sanitation, and the shortage of land on Funafuti is also a key issue.

Interviews held with the Presidents of several outer islands in Tuvalu and with the residents in both Tuvalu and Kiribati confirmed that they very much appreciated the improvements to the quality of life on the outer islands which are offered by PV lighting and related electricity services. Those interviewed also confirmed that they did not wish to move to the main islands on a permanent basis. Hence, it may be concluded that the provision of PV lighting has contributed - albeit possibly only in small measure, but combined with other improvements to the standard of living - to the willingness of the residents of the outer islands to remain there rather than to migrate to the main islands.

The key problem cited by the more dynamic residents of the outer islands was that of poor transport to the main islands, particularly in Tuvalu. Infrequent and relatively unreliable transport makes it difficult for politically or commercially motivated individuals to participate in the business of their country, and the effects can only be partially reduced by improvements to telecommunications. There are no obvious solutions to the problems of transport for the outer islands, because the underlying problem is one of cost, and it is not realistic to foresee long term subsidies for inter-island transport at a much higher level than already exists.

6.2.4 Job creation

The PV follow-up project has helped to establish both SEC in Kiribati and TSECS in Tuvalu on a more permanent basis, with associated benefits in terms of permanent jobs.

In Kiribati, SEC now employs 8 full time staff in South Tarawa and 5 field technicians (one on each of Nonouti, Marakei and Abemama, and two on North Tarawa). It also employs part time agents on 14 other outer islands, making a total of 27 jobs altogether. In Tuvalu, TSECS employs 3 full time staff in Funafuti and 7 field technicians, making a total of 10 jobs altogether.

In addition, the PV follow-up project has stimulated cash flows of fees at a level of about 3000 AUD / month in Kiribati and about 2500 AUD / month in Tuvalu, which facilitate economic activity through the local banks.

Through the capacity building which took place during the PV follow-up project, skills were developed in SEC which allowed the company to win other PV project work in Kiribati, as well as export orders for their locally manufactured PV system controllers.

7. Sustainability

7.1 GENERAL

The sustainability of the PV follow-up project cannot easily be separated from the long term sustainability of the on-going implementation of PV electricity services in the outer islands of Kiribati and Tuvalu. The PV follow-up project provided a substantial and very important input to the on-going implementation process, but could not have been expected to produce a totally sustainable result on its own.

In addition to the PV follow-up program, assistance has also been provided to support the solar electrification programs in both countries in a sustainable manner, as follows :

- the Forum Secretariat's Small Island State's Development Fund funded the construction of the TSECS head office in Funafuti.
- the Forum Secretariat's Energy Division (FSED) funded a review of SEC and hands-on provision of business management assistance to its staff.
- the Lome 3 PREP provided funds for a local training workshop for the outer island technicians in Funafuti. It also funded the participation of Tuvalu and Kiribati technicians on PV training courses in Fiji and Bangkok.
- JICA provided opportunities for technicians from both Kiribati and Tuvalu to undergo 3 months training in Japan on the technical and management aspects of PV.
- SOPAC reviewed the sustainability of the TSECS and provided a training attachment to the SEC for the Tuvalu Energy Planner.
- SOPAC continues to provide information and advice on request, and follow-up assistance based on its own and other reviews relating to SEC and TSECS.

Experience in the region to date, and experience elsewhere suggest that the long term sustainability of rural PV electricity services depends on a number of critical success factors, and the most important of these are described below.

7.2 GOVERNMENT POLICY SUPPORT MEASURES

7.2.1 Overall support for PV electrification in the outer islands

In the context of the Pacific Island states, where citizens have a strong loyalty to their communities and the public sector retains a relatively high profile in the day to day lives of the rural communities, it is very important that the governments should make clear their overall support for the implementation of PV rural electrification. This has been the case in both Kiribati and Tuvalu, and the views of the governments have been transmitted through their island councils to the population at large. Hence, there is a generally positive response at all levels to the use of PV in the outer islands.

A number of specific measures can be implemented by governments with a view to improving the long term sustainability of PV electricity services in their rural communities, and these are described below, together with comments on the extent to which more could be done in connection with each of these measures in Kiribati and Tuvalu.

7.2.2 Import duty

The PV follow-up project, like all aid funded projects in Kiribati and Tuvalu, was exempt from import duty. However, to encourage the further development of PV systems in Kiribati, the government has reduced the import duty to zero percent on PV modules and on ballasts for discharge lamps. In Tuvalu, import duty on ballasts for discharge lamps is also zero percent, but the import duty on PV modules is still set at 30%. One reason for this is probably that TSECS has not yet got involved in the selling of PV systems to private users, while SEC has already begun to sell PV components and systems on a commercial basis in Kiribati.

In both countries there is still a 30% import duty on batteries. One way that the governments could help to make PV systems more economically sustainable would be to reduce the import duty to zero percent for deep discharge batteries which are supplied for use in PV applications. This could have the added benefit that it might discourage the use in PV systems of inappropriate car batteries, which are currently a little cheaper in the Pacific than deep discharge batteries, but have a lifetime in PV systems which is little more than 1 year (compared with 5 years for deep discharge batteries).

Similarly, the governments might wish to review their import duties on energy efficient light bulbs, which would encourage energy savings from all forms of electricity generation, including PV systems.

See Appendix 12 for a summary of the relevant import duties in Kiribati and Tuvalu.

7.2.3 Government policy for outer island electrification

Both governments have firm policies for outer island development, aiming to ensure as far as possible that the existing residents of the outer islands are discouraged from migrating to the main islands. With these aims in mind, the solar energy companies SEC and TSECS have been given support over the years with the implementation of their projects, and are widely known and accepted as being the unique centres of expertise with responsibility for the installation and maintenance of PV systems in their respective countries.

The Kiribati government has made it clear that SEC and not the Public Utilities Board (PUB) is responsible for providing electricity in the outer islands. PUB knows from its recent Buota to Nabiena grid extension project that it would not be economic or practical to supply each outer island with its own electricity grid, and is therefore fully supportive of the government stance.

In Tuvalu there is a clear government commitment to the provision of basic electricity services in the outer islands, and to the restructuring of the TSECS (see Vision 2015, State of the Nation Address, June 1998). However, the government has not firmly committed itself to PV electrification in the outer islands and the Tuvalu Electricity Corporation (TEC) is still expressing interest in the possibility of establishing diesel grids on the outer islands, though it has said that it does not want to take over the running of the loss making grid on the island of Vaitupu, which is currently run by the island council. A more definitive policy for providing PV electricity services in the outer islands of Tuvalu would undoubtedly help the proposed restructuring of TSECS, perhaps most importantly because it would help to raise confidence in the future of the organisation. Greater confidence in the future of TSECS will be key to identifying a new high calibre Executive Manager and to obtaining further donor funds to refurbish the existing systems and increase the numbers of PV systems installed on each of the outer islands.

7.2.4 Political and legislative support for SEC and TSECS

The government of Kiribati has demonstrated its support for SEC by establishing it as a government owned corporation and a monopoly supplier of PV services with senior public sector officials and a representative of the Bank of Kiribati appointed to its Board of Directors. This level of political support provides international donors and equipment suppliers with confidence in the company, and allows the management team to operate effectively.

Historically, the government of Tuvalu has taken a more “hands off” approach, leaving responsibility for the direction of TSECS to its own Management Committee. More recently, however, the government has recognised the need to restructure the co-operative and, as discussed in section 2.3.6, there are several options available for this. Because the useful life of the batteries in the majority of the PV systems in Tuvalu is due to expire within the next 12 months, and there are insufficient funds in TSECS to replace them , it is now urgent that re-structuring take place as soon as possible, so that new management can seek donors who would be willing to finance the refurbishment of the existing systems and supply new ones. The findings of this evaluation suggest that to achieve long term sustainability, the TSECS should be restructured to operate along similar lines to those used by SEC in Kiribati (section 2.3.6 c).

7.3 ECONOMIC AND FINANCIAL VIABILITY

7.3.1 The role of aid funding in Kiribati and Tuvalu

When considering the financial and economic viability of the PV systems provided to Kiribati and Tuvalu under the PV follow-up project, it is important to remember that these remote island states cannot realistically be expected to operate and compete in global markets without some aid from the developed world. They have extremely limited resources and their potential for exports is heavily constrained by a number of factors, not least of which are their remote location and consequent high transport costs.

In order to put the economies of these two countries onto a more sound basis, Trust (or "Reserve") Funds have been established, which provide each government with an annual income that can be used for development. Each Trust Fund is carefully managed by its government, and an important part of the annual revenue from each fund is used to assist with development in the outer islands. Aid is also available on a project by project basis, from both multi lateral and bi-lateral aid agencies.

Electrification has for many years been supported by aid agencies on a project basis, on the grounds that it involves high initial capital costs which many developing countries cannot afford. In recent years, a number of developing countries have also tried to attract investment in electrification from the private sector ie: Independent Power Producers (IPP). However, investors from the private sector are naturally looking for a good return and therefore tend to focus their attention on urban grid markets where substantial growth can be expected. An IPP approach is therefore out of the question for the outer islands of either Kiribati or Tuvalu.

Rural electrification is important for the development of rural communities, but is seldom (if ever) profitable. It therefore has to be subsidised in some way, either by cross-subsidies from urban markets or by transparent subsidies from government. For the PV follow-up scheme, the subsidy was provided in the form of donor aid to cover the initial costs of purchasing and installing the PV equipment for a limited number of households, after which it was envisaged that this group of PV systems would become self financing for the future.

A vital issue which must now be addressed is how to finance the remaining stages of the PV electrification programme in rural Kiribati and Tuvalu in a sustainable way. At the time of the PV follow-up project, it was envisaged that new installations would be added at a rate of about 200 systems per year at least until a critical mass of about 1000 systems had been installed in each country. However, until now, no new funding has been made available for this.

Project by project funding is clearly not well suited for such an incremental programme, because of the heavy bureaucracy involved in getting each separate package approved and off the ground. Indeed, the PV follow-up project itself demonstrated the effects of delays resulting from project by project funding in Tuvalu, where it took so long to get the project started that by the time the equipment was delivered, changes had already occurred in the requirements for components to be supplied to those systems which were to be refurbished. Bearing in mind the relatively small size of the projects involved in these tiny Pacific island states, and their remoteness from the decision making teams in Brussels, the recent plans announced by the EC to move to a rolling aid programme (Development Support Programme) with greater local decision making and reduced administrative bureaucracy would appear to be well suited for funding the next stages of PV electrification in the region.

7.3.2 Financial viability of PV compared with alternatives

The analyses presented in Section 6.1 have demonstrated that the PV electricity service scheme which was implemented under the PV follow-up project is the most attractive rural electrification option for households in the outer islands from a financial point of view at the present time, and is likely to remain so for the foreseeable future. The monthly fees for the PV systems are broadly comparable with the costs of the kerosene lighting which is still widely used in the Pacific islands, but the PV systems offer more convenience, better reliability, improved safety and the added advantage of power for radios, and music cassette players. They can also be used for other domestic appliances as household incomes inevitably increase in the future. The other technical options all rely on regular fuel supplies, which are difficult to ensure on the outer islands, and have been shown to be either more expensive or unsustainable for a variety of practical reasons.

An important and fundamental reason for the financial viability of the PV follow-up project scheme is that the initial costs of the PV systems were paid for by donor funds. As a result, the users do not have to repay the initial capital costs of their systems and to pay for the on-going maintenance and future component replacement costs at the same time. As shown in section 6.1.1, the fees that the PV Utility would have to charge to recover both the initial capital costs and the on going O&M costs would be more than twice the monthly fees which are currently being paid in Kiribati and Tuvalu. Such high fees would simply not be affordable for a large proportion of the rural households concerned.

An extremely attractive feature of the financing scheme which was implemented through the PV follow-up project is that the PV Utility business becomes commercially viable for the long term, once the initial donor contribution to the capital costs of the equipment has been provided. This is because all of the future operating, maintenance and component replacement costs are then paid by the users. In contrast, most other electrification options involve requirements for long term subsidies, for example to cover staffing or fuel costs which are more difficult to support with aid funds.

Recent experiences in Vaitupu in Tuvalu and in North Tarawa in Kiribati - and elsewhere in the Pacific region - have demonstrated that small grids are not commercially viable / sustainable in these remote islands, even when the main generators have been donated, as was the case in Vaitupu. Whilst there are clear long term advantages to the introduction of 24 hour grid power from the users point of view (convenience and access to high power when needed), the very high costs involved, problems with fuel supplies, and overall lack of financial sustainability mean that grid power is unlikely to replace the PV option for the outer islands in the foreseeable future.

7.3.3 Economic viability

From a National perspective, the overall benefits resulting from PV electricity services all appear to be broadly sustainable in nature, and include savings in imported fuels, community development and social cohesion in the outer islands, reduced migration to the main islands, and new jobs created.

However, the sustainability of these benefits is heavily dependent on the long term sustainability of SEC and TSECS, since the PV systems will only continue to provide the necessary services if they are properly maintained and refurbished when the system components reach the end of their useful lives. Hence, the issues discussed in Section 7.7 (including the need for the restructuring of TSECS and for a new injection of donor funds to recover the losses caused by the TSECS's history of mis-management) are key to the long term economic sustainability of PV systems and services in Tuvalu.

Similarly, financing must now be provided for those households which were not able to benefit from the limited number of systems provided under the PV follow-up programme if the economic development objectives of the project are to be fully realised for the long term benefit of all of the communities concerned.

7.4 SOCIO-CULTURAL EMBEDDING

7.4.1 Willingness to pay for PV systems

Our analysis of the willingness and ability of people to pay is based on our discussions with the users and the solar energy companies, and on our review of their payment records. The users highly value the service that they receive from the solar lighting systems, and when asked if they were willing to pay, the answer was always yes! When asked if they would prefer to pay more than they were paying at the moment or have their system removed, they all said they would pay more to keep their systems, as long as the system stayed in good working order and the technician maintained it satisfactorily.

All of the households without PV lighting systems that we visited said that they wanted to have PV systems installed. The waiting lists held by both SEC and TSECS are also an indication of the demand for PV systems and the willingness of the families to pay. Indeed, many of them have already paid their AUD 50 deposit and are still waiting for a system to become available.

7.4.2 Ability to pay for PV systems

Most families who could afford the AUD 50 deposit are also able to pay the monthly fees. To put the monthly payments into perspective, the current levels of about 10 AUD per month are on a par with the monthly tithes paid to the church by each family. Families consider it very important to pay their monthly tithe to the Church, as it is frowned upon if they do not.

7.4.3 Payment records of SEC and TSECS

Our analysis of the available payment records at SEC and TSECS (see Appendices 10 and 11) shows that the collection rates in 1998 were slightly better in Kiribati (~60% of expected income to the end of September) than in Tuvalu (~52% to the end of July), but that a disturbingly high proportion of the users (almost 50% of all users) were paying more than 3 months late this year in Kiribati. It is however, encouraging to see from the SEC records that they had only about 4% of the 1997 fees outstanding at the end of last year, so it is to be hoped that the current situation will also be corrected by the year end.

Delays in the payment of fees are generally for one of the following reasons:

1. The field technician has not collected the money on a regular basis (2 technicians have already been sacked by SEC for this)
2. The family did not make enough income that month
3. The family is waiting for money to arrive from their son who is a seaman;
4. The system is not working
5. The family has spent its money on other things, often large one-time community obligations

7.4.4 Disconnection policies

Both SEC and TSECS have contractual disconnection policies with their users, and the technicians can relatively easily disconnect the systems inside the system controller. In June this year, TSECS instructed its technicians to reduce the length of time with non-payment before the user is cut off and the length of time with non-payment before the user has the system removed, in order to improve the on time collection rates in Tuvalu. They reported that on time collection rates had significantly improved as a result of this, so it remains to be seen whether or not they can correct their late payment status before the year end.

The collection of fees clearly needs to be backed up with stricter disconnection and system removal policies, which are readily enforced to make sure that fees are collected. The SEC records show that 10 systems were disconnected in Nonouti last year and a further 2 in Marakei. The families who were disconnected are now paying off their arrears, and SEC reports that several have asked to be put back onto the waiting list for another system. No data was provided by TSECS on their recent disconnection rates.

7.5 APPROPRIATE TECHNOLOGY

Detailed comments on each of the system components used in the PV follow-up project are given in Section 4.2.3.

The Siemens PV modules used are of the highest quality and appear to be operating well, despite the high humidity and high temperatures in which they have to work. They have a guaranteed lifetime of 20 years, which is very important bearing in mind that they are the most costly components in the system. They are well suited for this application, but it should be mentioned that other manufacturers can be expected to provide modules with a similar quality, so it is not necessary to select the same supplier for all future PV systems in the Pacific.

The Oldham batteries were also of the highest quality. They are of a deep discharge design, which has been specifically adapted for use in PV systems. These batteries are working well and are well suited for this application, but it must also be mentioned that they are somewhat more expensive than other deep discharge batteries which might be expected to operate well in isolated PV systems in this environment. Hence, once again, it is not necessary to select the same supplier for future systems.

The charge / discharge controller which is manufactured locally by SEC has been well adapted to the local conditions through a series of modifications, and is based on the GIE Soler controller which was initially made in Tahiti. This controller, which was generally found to be working well, employs a simple design with an open circuit board and two removable relays in a conventional weather proof plastic box. It can therefore be repaired / refurbished in the region by SEC or other trained technicians. Most PV system controllers on the international market today employ solid state electronic switching and sealed units, which cannot be repaired locally. Bearing in mind the remoteness of the Pacific islands, and the fact that local expertise is available to carry out repairs to the SEC units, it is clear that they are fully appropriate for use in this project. It should also be mentioned that the local manufacturing of the units created employment in Kiribati, and has subsequently led to export orders for SEC.

The lighting units and ballasts from Independent Power Ltd have proved to be generally reliable in the harsh Pacific climate, and the Philips PL lights were fully appropriate for use in this project. The cabling and other electrical components were of also appropriate, with the exception of the light switches and terminal blocks used for making cable connections, which were of inadequate quality. Whilst these are both very low cost items, they can cause important voltage drops if corrosion occurs on their cable connections, so more care should be given to the choice of light switches and terminal blocks in future.

A four LED night light was provided. Its inclusion was based on the observation that households operate a kerosene wick lamp at minimum level to keep away "ghosts" and to provide sufficient visibility at night to care for children, move around the house, etc. However, the night lights were found to be unused in many households because their light output was insufficient. There remains a strong need to develop and provide night lights with a higher light output and low power demand in order to reduce the incidence of households operating one of the main lights over night. New high intensity LEDs or electro-luminescent panels could be possible solutions to this problem.

7.6 ENVIRONMENTAL PROTECTION

7.6.1 PV battery recycling

Battery recycling plans and policies have not yet been implemented in either Kiribati or Tuvalu. This is partly because not many batteries have yet had to be replaced. However, the batteries are now reaching the end of their useful lives and, over the next one to two years, many will need replacing. A scheme is now needed through which the old batteries are exchanged for new batteries, and the old batteries are sent back to the main island for recycling.

Waste disposal in general is a big problem for the Pacific islands as there is little land to spare, and recycling of materials is essential to combat pollution problems. Aluminium drinks cans are already being recycled on the main islands, but it was unclear whether or not plastics and other inorganic materials are being recycled. The main elements of the deep discharge lead acid battery that need recycling are: the acid; the lead and the plastic casings. It was reported that some lead from car and truck batteries is being used for weights on fishing nets.

Small spillages of acid on the coral atolls is not too damaging, as the alkaline coral sand neutralises the acid quickly, but the uncontrolled disposal of large quantities would be damaging to the ecology of the atoll, especially if it were allowed to leach into ground water resources (in Kiribati in particular).

7.6.2 Displacement of dry cell batteries

Dry cell batteries are being displaced by PV solar power in appliances such as radios and cassette players, but not in torches. This is reducing the number of dry cell batteries, but not eliminating them. The disposal of dry cell batteries is not controlled or co-ordinated. They are just discarded on the ground outside people's houses and left to rot. Attention needs to be given to this problem before it gets any worse and the heavy metals in the batteries begin to pollute the ground water and / or the food chain.

7.7 INSTITUTIONAL MANAGEMENT AND CAPACITY

7.7.1 Overview

The success and long term sustainability of the PV Utility schemes in Kiribati and Tuvalu are heavily dependent on the management and technical skills of SEC and TSECS to provide the following services :

a) Appropriate system sizing and component selection to meet the needs of individual users

b) Good quality installation

c) Regular maintenance and checking for faults before any serious damage is caused

d) Regular collection of fees (strict enforcement of penalties and the disconnection policy)

e) Strict enforcement of the user contract to avoid abuse by unauthorised connections of appliances with high daily energy demands (user awareness and education)

f) Setting of fees which are both affordable and sufficient to cover PV Utility operating costs

g) Effective trouble shooting to deal with technical problems when they do arise

h) Timely replacement of components when they reach the end of their useful lives

SEC is proving to be generally successful in its management and operation, and has shown itself to be capable of delivering each of the items from (a) to (e) above on a regular basis. However, it still requires periodic high level guidance on items (f), (g) and (h).

In contrast, TSECS has had management problems which have left it in a situation where some of its staff lack the skills needed to deal with items (c) and (d), and the more complex items (e) to (h) are to a large extent outside the competence of the existing staff. Also, its current level of liquidity is so poor that it cannot afford to replace failed components or to improve the training of its staff.
A more detailed discussion of the sustainability of the PV organisations in Kiribati and Tuvalu is given below. Further information on SEC and TSECS is given in Appendices 10 and 11.

7.7.2 Sustainability of the PV Utility approach in Kiribati

The experience gained by SEC in Kiribati from the earlier PV project demonstrated that a sales approach to PV electrification did not work well in the Pacific. The approach adopted for the PV follow-up project in Kiribati was therefore built on the more successful aspects and operating experience of TSECS in Tuvalu with a "fee for service" or PV Utility approach.

Nine years after its implementation in Kiribati (following the reorganisation of SEC in 1990), the PV Utility is still working well, and there is sufficient cash on deposit in the Bank for SEC to replace the batteries as they reach the end of their useful lives over the next few years (see Appendix 10). However, it is important to recognise that this success has not been achieved without assistance from the former Forum Secretariat Energy Division (FSED) (more recently from SOPAC's Energy Unit) and periodic high level guidance from the original project consultant Herbert Wade, whose experience, commitment and readiness to provide guidance, when required, has undoubtedly contributed substantially to the success of the SEC operations in Kiribati.

It is also very important to recognise that the business plan for SEC was based on an on-going programme of 200 new installations per year to achieve a critical mass of 1000 PV systems under Utility management. This plan, which relies on donor aid to fund the initial costs of these 200 new installations per year, has not been realised since the end of the PV follow-up project, and therefore the PV Utility operation has depended on cross subsidies from the other work of SEC to remain commercially viable.

Key features of the approach, which lead to its long term sustainability include the ownership of the main PV system components (PV modules, cabling, battery and controller) by the Utility rather than the user. This allows the PV Utility to implement a strong disconnection policy for users who do not abide by the rules in the service contract. The records of SEC (see Appendix 10) clearly show that a small number of disconnections are made each year where users either do not pay their fees or where they abuse their systems by adding unauthorised loads. The strict implementation of this disconnection policy is vital to the sustainability of the scheme since it stimulates other users to pay up, and helps to minimise the number of late payments.

Fee collection is naturally a difficult matter for all Utilities. SEC has implemented a simple approach whereby the local field technician is required to visit each system once per month to clean and inspect the system, top up the battery and collect the fees. The visit allows him to check for unauthorised loads and to try to spot any potential problems with the system. The extent to which each field technician is able to achieve these aims depends on the skills of the individuals concerned. To meet this need, SEC operates regular technician training and has developed its own field technician selection procedure, based on its experience during the past few years. All of these developments suggest that there is a very good potential for the long term sustainability of the SEC PV Utility, provided that it continues to get the support of the government of Kiribati, a relatively small amount of high level guidance on a periodic basis as required, and donor funding for the proposed ~200 new systems to be installed per year - at least until the planned level of 1000 systems has been achieved.

The actual level of the fees charged is discussed in Section 6.1.1 and a spreadsheet for calculating the fees is presented in Appendix 9. These discussions showed that the current fee level in Kiribati of 9 AUD / month (10 AUD if a dc/dc converter is installed) is affordable by the majority of the households in the outer islands, and has allowed SEC to put enough money on deposit to pay for replacement batteries, but it is not really sufficient to cover the full operating costs of the PV Utility when only 300 systems are being managed. In reality, SEC is currently cross-subsidising its PV Utility operation from the profits made on its other project work, and this is not a sustainable approach for the long term As discussed in section 6.1.1, a detailed analysis of the costs of the PV Utility cannot be separated from the costs of the other operations of SEC, because the salaries of the senior staff and technicians must be spread across all aspects of the business, and these salaries form an important part of the overall PV Utility operating costs. The estimates made during this evaluation suggest that it might be wise to increase the monthly fees to (say) 12 or even 14 AUD per month, in order to ensure that the full costs of the PV Utility service are covered. However, such estimates need to be reviewed on a regular basis by the SEC management in the light of their expected future workload and the reactions of their clients to the proposed increase in monthly fees. Discussions held with users during the evaluation mission suggested that an increase to 12 AUD/month would be acceptable provided that the systems worked properly. Whether or not they would agree to a higher fee than this remains to be seen.

7.7.3 Sustainability of the PV Utility approach in Tuvalu

Although the early experience of TSECS was an excellent example of the PV Utility approach, and the Tuvalu experience was copied very successfully by others including Kiribati, the current situation in Tuvalu is extremely disappointing (see Appendix 11). The history of management problems in TSECS has left the organisation with an almost empty Bank account, and several technicians have not yet been trained to do much more than top up the batteries. The current situation in Tuvalu is far from sustainable and, unless the restructuring of TSECS which has been proposed by the government takes place urgently, there is a risk that the whole scheme in Tuvalu will fall into disrepute.

The fees being charged in Tuvalu are significantly lower than in Kiribati, at only 7 AUD/month, and the on time collection rates are also lower. Attempts were made during June 1998 to toughen up the disconnection policy with a view to achieving higher on time collection rates and to some extent the result has been encouraging. Indeed, this demonstrates the continuing goodwill of the population towards the use of PV systems, and their strong desire to have them. However, TSECS does not have any other business which would permit it to cross-subsidise its PV Utility operation in the same way as SEC, so its monthly fees are slowly declining as the number of failed systems increases because it has not enough cash to purchase the necessary spare parts.

At the time of the evaluation mission, the monthly fees were only slightly above the monthly salary bill for the permanent staff of TSECS, and there was insufficient cash in the Bank to pay for a meeting of the Management Committee. The telephone to TSECS had been cut off because the bill had not been paid, and there were almost no spare parts or tools in the store.

There is every reason to expect that a restructured TSECS will be able to operate a fully sustainable PV Utility scheme for the outer islands of Tuvalu, with affordable monthly fees. However, a detailed study is now required to develop a new business plan for TSECS, once the basic restructuring plans have been implemented by the government. Only when this has been done will it be feasible to determine new fee rates for use in Tuvalu.

8. Conclusions & Recommendations

8.1 CONCLUSIONS

The data gathered and discussions held during this evaluation have shown that the original ***objectives*** of the Pacific Regional Energy Programme have been achieved by the PV follow-up project, namely to reduce dependence on fossil fuels and to prove the suitability of PV technologies for the region. *(We estimate a substitution of ~1% of all annual petroleum fuel used or ~10% of that used in household sector, and a saving of ~400 tons of CO_2 per year. More than 95% of the ~300 PV systems in Kiribati were working well, though the performance of >25% of the ~400 PV systems in Tuvalu appeared to be less than optimum).* The original PREP objectives, however, no longer have the highest priority for the two governments concerned, which are now more worried about raising the standards of living on their outer islands, reducing migration to their main islands and creating sustainable jobs. We were pleased to discover that the PV follow-up project is contributing to these more recent objectives as well *(eg: better lighting is improving the quality of life for families; PV medical refrigerators are improving health care; 13 full time and 14 part time jobs have been created by SEC in Kiribati and 10 full time jobs have been created by TSECS in Tuvalu)*, and there is evidence to suggest that further PV electrification could do even more in the future, if sufficient financing can be obtained to expand its implementation.

The PV follow-up project was implemented on a ***Regional*** basis, which brought a number of benefits, notably in terms of economies of scale in the purchasing of PV system components in international markets and in terms of the shared costs of training. The tendering procedures adopted for the PV follow-up programme were also managed on a regional basis, because tenders were let for equipment supply only. This was important for the capacity building element of the PV follow-up project, which ensured that the local companies (SEC and TSECS) could be trained at the same time to select the best hardware and to learn from the experience of installing the systems themselves. This experience was vital to the future sustainability of their PV Utility schemes. From an administrative point of view, it also allowed the EC officials access to the regional expertise of the Forum Secretariat Energy Division (FSED) and more recently - since the transfer of the regional energy programme in January 1998 - the South Pacific Applied Geoscience Commission (SOPAC). When considering future projects in the Pacific Region, it is important to remember the isolation of the individual Island States, and their remoteness from the aid agencies that support them. In this context, the existence of regional centres of expertise, such as the Forum Secretariat and SOPAC, that can be called upon for advice and assistance by the different project sponsors and Island State Governments, would appear to be invaluable.

The main ***impact*** of the PV follow-up project has been to provide good quality, convenient and safe lighting for ~34% of the outer island households in Tuvalu and ~4 % of the outer island households in the Gilbert Group of Kiribati, together with affordable access to radio and cassettes players. These concrete benefits have in turn led to better living conditions for individual householders, which together make the environment of the outer islands a nicer place to live. The overall result is a widespread and frequently stated demand for more solar lighting in the outer islands. All of those interviewed stated that they were satisfied with their solar lighting, many said that they were pleased with it, and some also stated that they now found their lifestyle more pleasant on the outer islands than on the main island. *(The field technician in Nukufetau showed us his waiting list of households who had paid a 50 AUD deposit and were waiting for a PV system; it had more than 15 names on it. He also told us that he would not take money from more households until he knew when he could supply them with a PV system).*

In summary, it has been shown that there is ***still a demand*** for at least **3,500** more PV household lighting systems in the outer islands of Kiribati and 400 - 600 more PV household lighting systems in the outer islands of Tuvalu. In addition, there is also an unsatisfied demand for PV lighting and small power in community halls, schools, and other public places in the outer islands.

The PV ***technology*** used in the project was of the highest quality and was well suited to the local conditions. The ***system sizing,*** at about 100 Wp per household, is well suited to the needs of the majority of users (though the richer families may wish to expand their systems in the future). The size of the PV generator is larger than would normally be offered by most international PV system suppliers for purchase by an individual user with only lighting and radio loads, but this size is justified for systems which are designed for long term operation and ownership by a PV Utility service, where the lifetime of the battery is vital to the economic sustainability of the business. By slightly "over-sizing" the PV generator, compared with common practice in developed countries, the PV Utility can ensure that the battery is regularly overcharged and therefore that its electrolyte is well stirred and its life maximised. With this design, some loss of energy due to ageing of the modules and battery, and some corrosion of the cable connections can be accommodated without a noticeable reduction in service, though regular topping up of the batteries is vital to achieving the designed battery life of ~5 years.

The transport of liquid fuels to the outer islands is likely to remain a major problem for both Kiribati and Tuvalu in the foreseeable future. The practical difficulties associated with transporting fuel to these remote islands, involving cumbersome and labour intensive transfers by small boat and rolling drums up the beach, contribute significantly to the argument that ***PV electricity is more appropriate*** for use in the outer islands than diesel or other fuel based power generation.

The ***institutional framework*** which has been developed for the provision of the " PV Utility" service in both countries is based on the model which was first developed very successfully by TSECS in Tuvalu and later adapted and improved upon by SEC for use in Kiribati. This scheme is both technically and economically appropriate to the conditions in the outer islands, and is also the most cost effective and sustainable solution for these locations, when compared with the available alternatives. Provided that financing to purchase the initial PV hardware is provided by donor aid, and provision is made for a small amount of high level guidance on an on-going basis, then the experience of SEC has shown that the installation, maintenance and supply of spare parts can be managed on a sustainable commercial basis, without the need for Government subsidies. Continuing political support from the government is however still very important to the long term sustainability of the PV Utility schemes, for example through government officials serving on the Boards of Directors of the solar companies and also by practical measures, such as the reduction of import duties on PV system components and official promotion of PV electrification for the outer islands.

SEC and TSECS have developed unique expertise in the establishment and management of PV Utility services, and SEC is currently performing very ***successfully*** as a business. However, the PV Utility operations of SEC are far too small to be sustainable without continuing subsidies from its other project work, so it is not yet ready for full privatisation. Moreover, the scale of the PV electrification programme in Kiribati would have to be increased by a factor of between 5 and 10 before it would be commercially feasible for another company to compete with SEC in the local PV Utility market, and it would make no sense to privatise SEC as a monopoly.

A fundamental reason for the financial viability of the PV Utility scheme which was implemented in the PV follow-up project is that the initial costs of the PV systems are paid for by ***donor funds***. This means that the users do not have to repay the initial capital costs of their systems and to pay for the on-going maintenance and future component replacement costs at the same time. If the PV Utility would have to recover both the initial capital costs and the on-going O&M costs at the same time, then the fees would be more than twice those which are currently being paid in Kiribati and Tuvalu. Such high fees would simply not be affordable for a large proportion of the rural households concerned. It follows that loan based PV electrification in Kiribati and Tuvalu would be unlikely to meet the development objective of providing affordable lighting and electricity services to the majority of the rural population.

An extremely attractive feature of the PV Utility scheme is that the business becomes commercially viable for the long term, once the initial donor contribution to the capital costs of the equipment has been provided. This is because all of the future operating, maintenance and component replacement costs are then paid by the users. In contrast, most other electrification options require long term subsidies (eg to cover staffing or fuel costs) which are more difficult to support with aid funds. *(Note: The option of selling PV systems to users and letting them finance them through private sources and/or soft personal loans was shown to fail in the Pacific in the earlier PV projects and should not be repeated. Such an approach encourages the purchase of poor quality components, and minimal maintenance which together lead to early failures and a lack of long term sustainability).*

The current operations of TSECS in Tuvalu are ***not sustainable***, largely because of the institutional framework under which the co-operative society was originally established. The TSECS is managed without direct support from government, and is under the control of a Management Committee whose members typically have little or no local or international business expertise. As a result, the organisation has been poorly managed over a period of several years and is now fast approaching a financial crisis. This situation has been appreciated by the Government of Tuvalu who have confirmed their intention to restructure TSECS. Until TSECS has been restructured, it would make no (economic) sense to invest in new PV systems or in further PV training there. The most helpful step that any aid donor could take in the near future would be to work in partnership with the Government of Tuvalu to achieve the required restructuring of TSECS. For example, the new rolling EU Development Support Programme could contribute here, initially by supporting the restructuring process, possibly with help from the Special Projects Unit in the Prime Minister's Office.

The availability of PV electricity has brought a wide range of ***benefits*** to the outer island communities, even though it has not yet led directly to the introduction of new income generating activities. *(This is mainly due to the isolation of the communities and their lack of access to markets, as well as the limited resources from which they can generate incomes, ie: fish, copra, and leaves or shells for handicrafts).* Examples of the benefits identified during the evaluation mission include : fishermen told us that they used solar lighting to prepare their catch at night, pastors stated that they used the lighting to read and prepare their sermons, medical assistants were seen working by solar lighting at night, vaccines were seen stored in solar powered refrigerators, a school was found to be using PV electricity to power personal computers and printers, children were encountered listening to solar powered music cassette players, and several families were found to be using solar powered CB radios to communicate with their distant relatives.

The PV lighting systems which have been implemented through the PV follow-up project are ***affordable*** by the majority of the population. The sample of households interviewed during this evaluation confirmed our estimated range of household incomes (typically 150-300 AUD/month) and that a PV Utility fee of 10-12 AUD/month is acceptable to them. (This level of fee is comparable with their monthly tithes to the church). The existing fee levels need to be increased in both Kiribati and Tuvalu to ensure long term sustainability, and the fee collection rates for the first half of 1998 in Kiribati (60%) and Tuvalu (52%) also give cause for concern. Stricter enforcement of the companies' disconnection policies is necessary to ensure that sufficient fees are collected. In order to ensure the long term ***sustainability*** of the PV Utility operations, whilst keeping fees at a level which is affordable by the poorer households, the number of systems in each PV Utility scheme should be increased to at least 1000.

8.2 RECOMMENDATIONS

8.2.1 Increase the number of PV systems in Kiribati

The Government of Kiribati should work with SEC to secure new donor financing to pay for ~200 new PV systems per year over the next 5 years with the aim of increasing the number of PV systems in Kiribati to more than 1000. This will make an important contribution to the quality of life in the outer islands, create new jobs, and allow the SEC PV Utility service to achieve long term sustainability whilst maintaining fees at a level which remains within the reach of the poorer households. *(Note: a rolling funding scheme which will not incur significant delays would be ideally suited for this work. Alternatively, it would be desirable to establish a 5 year project with independent management assistance)*

8.2.2 Restructure TSECS as a government owned Corporation

The opportunity should be taken as a matter of urgency to build on the earlier successes of TSECS and to restructure it as a separate government owned Corporation (similar to SEC) with a Board of Directors consisting of senior government officials and a representative from the National Bank of Tuvalu(preferably the General Manager). At the same time, support from an aid donor should be sought to refurbish the existing PV systems, train the new managers and technical staff, and establish comprehensive stocks of spare parts, proper stock control, accounts and business management systems. Once the restructuring of TSECS has been completed and the business fully re-established, then further consideration should be given to installing new PV systems. It is estimated that a further 400-600 PV systems will be needed to complete the rural electrification programme in the outer islands of Tuvalu.

A high ranking Honorary Chairman should be nominated for TSECS by the Minister of Works, Energy and Communications, and an appropriate salary offered to attract an Executive Manager, who is experienced in international procurement and business practices. In order to give confidence to aid donors that it is fully committed to PV electrification in the outer islands, the Government of Tuvalu should offer to repay the membership fees to existing members of the co-operative (up to 20,000 AUD) as part of the restructuring

process and, in addition, should inject an appropriate amount of working capital to establish the new Corporation on a sound financial footing.
(Note: The Energy Co-ordinating Committee is responsible for restructuring TSECS, with support from the energy advisers of SOPAC, and overall approval will be needed from the Cabinet. To complete the restructuring as quickly as possible, it is recommended that additional support be provided by the Special Services Unit in the Prime Minister's Office)

8.2.3 Do not privatise SEC in the near future
The Government of Kiribati should reconsider its proposal to move SEC into the private sector in the near future. There are no clear benefits from the privatisation of a monopoly, and it would not be commercially viable for another company to compete with SEC until the PV Utility market is about 10 times its existing size. Furthermore, the PV Utility business of SEC is not sustainable at its present size, and needs to be increased to more than 1000 systems before it would be a sustainable business without cross subsidies from SEC's other project work.

8.2.4 Provide advanced training for PV Utility staff
A new package of training should be provided to develop the technical skills of a small number of senior technicians in trouble shooting for the more complex problems which are now appearing in the older PV systems. This would be a logical follow-up to the earlier training on installation practices and routine maintenance procedures.

Similarly, a package of advanced training is needed to develop the business skills of the solar company staff in stock control, international procurement, and business management.

These training packages are urgently needed by the staff of SEC in Kiribati, but would also be of benefit to those who are responsible for PV Utility operations in other Pacific island states, including the team which is to manage the restructured TSECS operations. This training could therefore either be provided on a country by country basis or as a regional training initiative.

8.2.5 Reduce import duties on deep discharge batteries for PV systems
The existing duty of 30% should be reduced to zero % for deep discharge batteries which are intended for use in PV systems. This would help to discourage the use of inappropriate car batteries in PV systems and make the more sustainable designs more affordable for private users.

8.2.6 Reduce import duties on energy efficient light bulbs
The existing duty of 25% on all light bulbs should be reduced for the energy efficient fluorescent designs to zero %. This would not only help to reduce the costs of PV lighting systems, but would also encourage energy savings in the grid connected houses on the main islands.

8.2.7 Reduce import duties on PV modules in Tuvalu
The Government of Tuvalu should follow the example set by Kiribati and reduce the import duty on PV modules from 30% to zero %. This would help to encourage the use of this clean energy source for a wide range of private applications.

8.2.8 Reduce import duty on cables in Kiribati
The government of Kiribati should follow the example set by Tuvalu and reduce the import duty on cabling for use in PV systems from their current level of 50% to zero %, in order to encourage the use of high efficiency PV systems.

8.2.9 Install some larger "pilot" PV systems in Kiribati
As part of the next phase of PV electrification in Kiribati, a number (say 10) of larger PV "Pilot" plants should be installed to build local experience with such systems. These systems should be large enough to power a video or domestic refrigerator in addition to the normal household lighting, and so should have a power rating of 400 - 500 Wp. One or two such systems should also be installed to power lighting for community maneabas. *(In contrast to the less successful "pilot projects" in Tuvalu, these plants should be properly monitored for a period of at least two years in accordance with the EC PV Plant Monitoring Guidelines.)*

8.2.10 Encourage more local manufacture of PV system controllers

Future projects in the region should encourage the production (and development as necessary) of the controllers which have been manufactured locally by SEC, with a view to expanding the potential for local job creation and exports.

8.2.11 Provide more PV lighting and power for computers in schools

Advantage should be taken of the experience which has been gained with PV systems in the secondary school on Nonouti, and more PV systems should be installed to enhance the education of children in both Kiribati and Tuvalu.

8.2.12 Improve sales and distribution of PV light bulbs

The distribution of high efficiency light bulbs (eg: Philips PL) was found to be weak in Kiribati and in Tuvalu. Both SEC and TSECS should review the ways in which they are marketing replacement light bulbs and seek cheaper and more effective ways to ensure that their users can obtain light bulbs easily and at minimal cost.

8.2.13 Establish a battery recycling scheme

A large number of lead acid batteries will need to be replaced during the next two years in both Kiribati and Tuvalu. The old batteries need to be removed from the outer islands and disposed of without causing environmental pollution. The respective governments should ensure that SEC and TSECS take responsibility for removing the old batteries and arranging for them to be recycled (possibly in Fiji).

8.2.14 Improve training / repairs / spare parts support for medical refrigerators

Spare electronic and electrical components for medical refrigerators should be stored locally in accordance with World Health Organisation guidelines, and senior technicians should be given more training on how to replace these components and/or to repair the refrigerators locally. Also, each new member of medical staff appointed to work in an outer island health centre should be briefed by SEC or TSECS on how to use the PV medical refrigerator and PV lighting system, and users' manuals should be provided in each health centre. *(Reliable PV medical refrigerators, PV lighting and communications systems are very important to the quality of care provided by the health centres on the outer islands, but the condition of those inspected during this evaluation was disappointing).*