Solar-based rural electrification policy design: The Renewable Energy Service Company (RESCO) model in Fiji

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Abstract

Solar photovoltaic technologies have for some time been promoted as a cost effective means of rural electrification in developing countries. However, institutional structures resulting in poor maintenance have adversely affected the sustainability of past solar projects. In Fiji, the Renewable Energy Service Company (RESCO) program is the latest attempt to promote solar-based rural electrification in a fee-for service model, aiming to remove the high upfront capital costs associated with solar technologies and using a public private sector partnership for maintenance. This paper assesses the program using survey and interview data. Major flaws are identified, relating to incorrect treatment of principal-agent problems, information asymmetries, motivational problems, and resourcing of government agencies. General lessons for fee-for-service solar home system models emerge, including that incentives for stakeholders must take centre stage in designing and administering such programs, and that active government support and ownership are required to make programs sustainable.

Keywords: SHS, Solar home systems, Solar, Rural electrification, Fiji, Small island developing states (SIDS)

1. Introduction

Solar photovoltaic technologies have for some time been promoted as a cost effective means of rural electrification in developing countries. The provision of lighting by solar home systems (SHS) is particularly promising for poor and remote communities, where 'traditional' lighting sources are of poor quality and pose substantial health risks [1-4]. However, the growth of markets for solar-based rural electrification has been slow, due to high upfront costs, a lack of credit in rural areas, and low service standards. This paper begins by briefly outlining the evolution of institutional models used to promote solar-based rural electrification in the Small Island Developing States of the South Pacific. The main focus of the paper is the Renewable Energy Service Company (RESCO) program, which is based on a fee-for-service model and is the latest attempt at solar-based rural electrification in the Fiji Islands. Survey and interview data are presented that casts doubt on the quality of maintenance services provided by the RESCO program.

The discussion that follows explains poor maintenance by analysing incentives and institutional arrangements under the program. Information asymmetries are shown to result in a range of

principal-agent and motivational problems, which are not overcome through mechanism design. In fact, incorrect treatment of principal-agent problems through inadequate monitoring provisions actually generates perverse incentives for the private sector company responsible for maintenance. The result is that the RESCO program fails to achieve incentive compatibility, with stakeholder incentives under the program not always aligned with ensuring SHS functionality or sharing information. The reasons for this can be found at the policy level, where a lack of interest in the program by successive governments has meant that institutional arrangements under the RESCO program differ to those originally proposed by donors. Inadequate resourcing of the Department of Energy has also adversely affected sustainability of SHS under the program.

The paper concludes that the RESCO model has failed in Fiji primarily as a result of the way it has been implemented, and that some modest changes to the program at the policy level could overcome these weaknesses. General lessons for fee-for-service SHS models also emerge, including that incentives for stakeholders must take centre stage in designing and administering such programs, and that active government support and ownership are required to make programs sustainable.

2. Solar-based rural electrification

Solar home systems (SHS) have several advantages over other technologies for the electrification of rural areas where extension of the electricity grid is unlikely in the near or medium term. First, their respective life cycle costs are generally lower than those of 'traditional' lighting sources used in developing countries, such as paraffin lamps, and are comparable to those of diesel or gasoline fuelled generators [5,6]. Second, SHS are modular in nature, which makes them suitable for rural areas, where demand for electricity is low, while providing households with the option of expanding their system size as demand for electricity increases (usually as a result of income growth) [7]. Third, SHS are particularly suited to areas where irregular and unreliable transportation poses a problem for the importation of fuel or spare parts for generators.

These advantages are highly relevant for Small Island Developing States, including those in the South Pacific.[1] Large areas in many of these countries are not reached by the electricity grid, the expansion of which is limited due to populations that are widely dispersed over various islands, and low incomes that restrict demand for electricity [8]. Off-grid village-based diesel generators provide an alternative, however suffer from unreliable transportation, and often require more maintenance than SHS as a result of moving components [9,10]. Solar technologies that provide limited power for lighting and other basic services potentially provide a cheaper and more reliable solution.

The challenges faced in the Fiji Islands are typical of those present in other Small Island Developing States. Fiji is made up of approximately 320 islands, of which 106 are permanently populated. The electricity grid extends to only three of these islands, and will not expand to other islands in the

[1] The 'South Pacific' here refers to the independent states of Vanuatu, the Solomon Islands, the Fiji Islands, Tonga, Samoa, Niue, the Cook Islands, Tuvalu, Kiribati and Nauru, as well as a number of dependencies such as New Caledonia and French Polynesia. Many of the advantages of SHS are also relevant to Pacific island states and dependencies that are north of the equator, such as Palau, the Federated States of Micronesia, the Republic of the Marshall Islands and Guam.

foreseeable future. This means that there are communities comprising about 26 per cent of Fiji's 837,000-strong population that could be served by off-grid solar systems [11]. Furthermore, several surveys of energy expenditure in rural areas have found that current expenditure on lighting fuel in unelectrified areas exceeds the life cycle cost of solar-based lighting [12,13]. The majority of unelectrified households could therefore afford the services of basic lighting provided by solar technology if the costs were charged on a life cycle basis.

Despite these advantages, growth in the use of SHS has been slower than was once hoped for in Small Island Developing States, and throughout most of the developing world. The performance of solar technologies has also been mixed [14,15]. Several barriers to the diffusion of SHS in developing countries have required interventions by governments or donors to promote the technology. These barriers can be broadly placed into two categories:

(i) High upfront costs that often make SHS unaffordable for rural households, for whom credit is difficult to access. In some cultures this barrier is compounded by the lack of a savings tradition, such as among indigenous Fijians.

(ii) Technical problems with SHS, which have often had their origins in the failure to establish appropriate institutional structures to ensure systems are maintained [15-18].

3. Institutional models for solar-based rural electrification

Interventions by donors and governments have sought to support and subsidise SHS in response to these barriers. Various institutional arrangements have been used to support solar-based rural electrification, including donations or subsidisation of equipment, the provision of consumer credit, and fee-for-service models [14,15]. Results have been mixed, and often vary depending on where measures are implemented. For example, in several cases where credit has been provided to rural households for SHS, users have opted not to pay technicians to provide maintenance and SHS have eventually fallen into disrepair, upon which repayments to the financing agency stop [14,15]. Ensuring that institutional arrangements exist to provide adequate maintenance has therefore been particularly challenging. In response to the poor sustainability of SHS, governments have often established standards for SHS equipment and servicing, and have been involved in the formation of training programs for solar technicians, again with mixed results.

Although there are success stories, no 'perfect' institutional model for solar-based rural electrification has emerged. Rather, the appropriateness of each model seems to depend on social, economic, political and cultural features of the community where systems are installed. This is to be expected, as the user always has some impact on the level of maintenance and repayment of SHS. Nieuwenhout et al. [14,15] also note that in practice, the identification of appropriate institutional arrangements for solar-based rural electrification generally involves substantial trial and error.

In the South Pacific, the most common form of SHS installation has been through donor-funded programs where users are given highly subsidised or free systems. This model recognises that most rural communities in the South Pacific have low cash incomes and rely on subsistence agriculture for their livelihoods, making them unlikely to afford the upfront cost of an SHS. Unfortunately, the majority of SHS installed under these programs in the South Pacific have failed, often as a result of

the inadequacy of institutional structures created to maintain such systems [8,18-21]. A key problem in the past has been that programs emphasised the hardware component of SHS (the technical and financial aspects), without adequately focusing on the software component (the social and institutional aspects) [19,22]. For example, programs often trained village technicians for basic SHS maintenance, only for those technicians to move to urban areas where they could now find skilled work. The collection of fees for purchasing replacement components (such as batteries) was also generally left to the community, with the result that insufficient funds were set aside [16,18].

A response to these failures in the South Pacific has been the movement of maintenance and fee collection to institutions that are external to communities. In the Fiji Islands, subsequent solar installations involved oversight by Government technicians who were also responsible for fee collection. This move had mixed results. In the case of 63 systems installed in Namara village in 1993, the model was quite successful, with most systems operational after 10 years. In Naroi village however, problems were experienced after the installation of 170 systems in 1999, due largely to the unavailability of parts locally [16]. This and similar experiences elsewhere in the South Pacific have shown that Government oversight of maintenance does not guarantee good maintenance.[2]

4. The RESCO model in the Fiji Islands

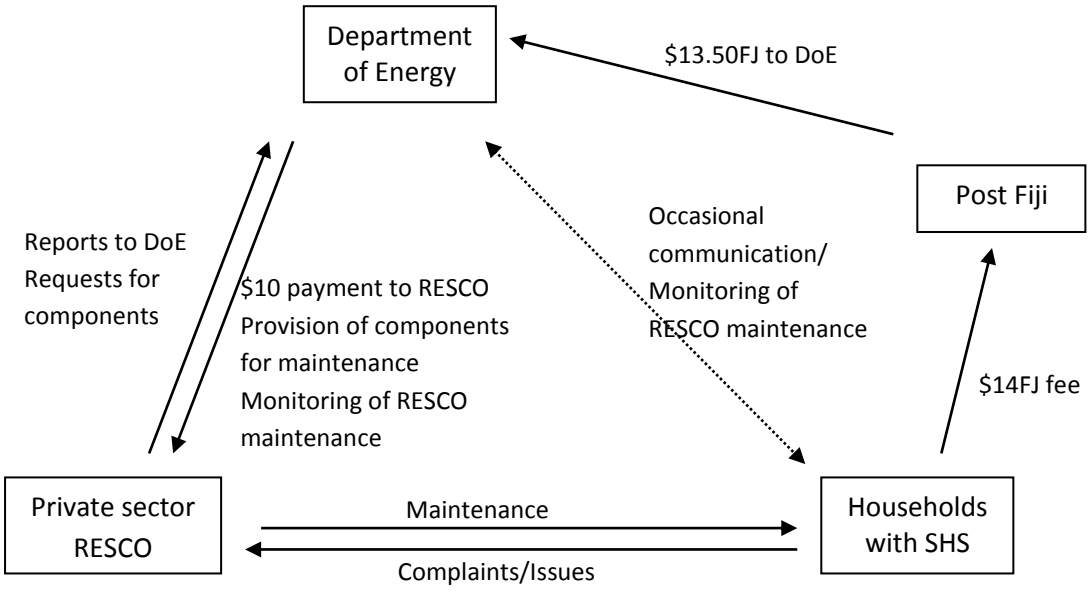
The Renewable Energy Service Company (RESCO) program is the latest attempt to promote solar-based rural electrification in the Fiji Islands, and can be understood as a response to past problems with community and government provided maintenance in Fiji. The fee-for-service model on which the RESCO scheme is based moves the responsibility for maintenance from communities and Government to the private sector, in the form of a public-private sector partnership [16,23]. The program is inspired by the success of fee-for-service models in other developing countries, such as nearby Kiribati, Zambia and the Dominican Republic [10,14,16,24]. It has its origins in a pilot project implemented by the US-based Pacific International Centre for High Technology Research (PICHTR), which was later transferred to the Department of Energy.

Under the RESCO program, SHS remain the property of the Department of Energy, which pays a contractor (a RESCO) from the private sector to provide maintenance. SHS installed under the RESCO scheme provide lighting and one DC power point for powering a small radio. They consist of two 50W panels, a 12 V Battery and a prepayment meter/controller (Interviews with Department of Energy staff, 2009). The upfront cost of each system amounts to $4065FJ (about $2073US)[3] and is paid by the Department of Energy.[4] Households pay an initial deposit of $50FJ, thereafter 'renting' the SHS for a monthly fee of $14FJ, which is paid at the local post office in return for a token that must be entered into the SHS prepayment meter. This amount is supposed to cover all maintenance costs and 5 per cent of the capital cost of SHS, consistent with Fiji's Rural Electrification Policy. The Department then pays the RESCO approximately $10FJ per month for each household under its

[2] Country summaries from the Pacific Islands Regional Energy Project provide a good overview of experience with SHS in the South Pacific. The reports are available at: http://www.sprep.org/climate_change/pirep.htm.
[3] $1FJ was equal to approximately $0.51US in May 2010.
[4] A financial feasibility study of the RESCO program conducted in 2003 estimated that the capital cost of each SHS would be $2916FJ, rising to $3236FJ in 2010. The difference with the current cost of SHS is due to the 20 per cent devaluation of the Fiji Dollar in April 2009.

maintenance contract. Payments to the RESCO are made every two months, during which time the RESCO is expected to visit every household with an SHS once. During these visits, technicians check the water levels of batteries and test the output of the batteries and panels. Where batteries or lights have failed, RESCO technicians make a note and report this to the Department of Energy. The Department uses the remaining money to purchase replacement parts, such as batteries and light bulbs, and sends these to the RESCO for installation in their next round of maintenance visits. These arrangements are illustrated in Fig. 1.

Figure 1. The RESCO Model



An advantage of the RESCO program is that it removes the high upfront capital costs that users face by maintaining government ownership of SHS. This has resulted in a surge of demand for solar systems on the island of Vanua Levu, where the program is being trialled, with 1040 installations as of December 2009. Indeed, there is currently a long waiting list for system installations, and there are also plans to expand the program to other islands of Fiji. However, there are concerns in the Department of Energy that the $14FJ monthly fee is not sufficient to cover all costs associated with equipment replacement. Indeed, it was estimated in 2006 that a $21FJ monthly fee would be required for this to occur [23]. This figure is likely to be higher now given the 20 per cent devaluation of the Fiji Dollar in April 2009. The current fee level therefore means that a subsidy is required from the Department of Energy to ensure that maintenance is provided under the scheme (Interviews with Department of Energy staff, 2009).

5. Performance of the RESCO model

5.1. Method

A survey and semi-structured interviews conducted in Fiji's northern island of Vanua Levu in November and December 2009 illustrate how the RESCO model has performed in two rural communities: Nakawakawa and Vunivao. They also give an indication of broader performance throughout the rest of Vanua Levu. Two communities that were electrified using diesel generators were also included in the survey. A random sample of approximately 20 households was selected from each community. In the indigenous Fijian village of Nakawakawa, this represented almost all households with SHS, while in the Indo-Fijian settlement of Vunivao, it represented close to one quarter of all households.[5] Households were asked questions relating to (i) the services provided by SHS, (ii) the performance of SHS, and (iii) maintenance of SHS. Responses concerning power outages were later corroborated against the records of the RESCO and the Department of Energy. Interviews were also held with Department of Energy staff and management, several government ministries and agencies, and RESCO personnel. The findings indicate that there are serious problems with the way that the RESCO program has been implemented. This is consistent with previous findings [25,26].

5.2. Results

The survey results clearly show that households were unsatisfied with the maintenance provided under the RESCO program (Table 1). Households were asked whether maintenance was a) very satisfactory, b) satisfactory, or c) unsatisfactory. Not one household in Vunivao and less than one quarter of households in Nakawakawa considered maintenance satisfactory.

Table 1. Opinions of SHS Maintenance.

Is maintenance provided under the RESCO program:	Very satisfactory	Satisfactory	Not satisfactory
Nakawakawa	4	1	16
Vunivao	0	0	20

The survey results illustrated in Table 2 indicate the reasons for this dissatisfaction. Households were asked about the length of the longest continuous power outage that their system had suffered. What is striking is the number of days that households in Vunivao have gone without power when their systems failed, with the average length of the longest power outage being 497.19 days. The averages were dragged higher by the relatively large number of households whose systems had not worked for some years, mainly as a result of prepayment meters not functioning. The figures in the other communities surveyed were also high. In Nakawakawa, the average length of the longest power outage for households was about 132 days, while it was slightly less in the two villages with

[5] Fiji is ethnically diverse, the legacy of a colonial policy that brought indentured Indian labourers and their families to Fiji to work on the sugar plantations. The 2007 census showed that indigenous Fijians comprise almost 57 per cent of the Fiji's 837,000-strong population, with 40 per cent of the population being Indo-Fijian. In rural areas, indigenous Fijians generally live in villages where houses are spaced closely together, while Indo-Fijians live in settlements where houses are spaced further from one another with plantations in between them.

diesel generators. The reason for the variation between the two communities with solar systems is the age of the SHS installed. Vunivao was the first community where SHS were installed under the RESCO model, with most installations occurring between 2000 and 2002. Nakawakawa on the other hand had its SHS installed in 2005, meaning that households were less likely to have experienced technical problems.

Table 2. Length of Longest Household Power Outage (in days)

	Solar Home Systems		Village-based Diesel Generators	
	Vunivao settlement	Nakawakawa village	Dama village	Wairiki village
Average (days)	497	133	117	98
Median (days)	365	75	105*	98

* Records of the longest power outage suffered by the diesel generator in Dama were inconsistent.

Households were also asked about the reasons for power outages that had occurred in 2009 and 2008. Causes of power outages included technical problems and not being able to pay the SHS fee or buy fuel, either because there was not enough money collected or available, or because they were unable to travel to the store or post office to buy fuel or SHS tokens. Table 3 shows that for households with SHS, technical problems were responsible for most power outages in both 2008 and 2009, whereas for villages with diesel generators the biggest problem was the collection of sufficient funds to purchase fuel. Technical problems faced by households with SHS were usually simple to address, predominantly involving the replacement of batteries or light bulbs (although there were some problems with the prepayment meters in Vunivao that were more complex).

Table 3. Reasons for Power Outages in Surveyed Communities (average number of days in 2008 and 2009).

	Technical Problems		Not enough money/ money not collected		Could not purchase fuel or SHS token	
	2009	2008	2009	2008	2009	2008
Solar Home Systems	147	87	3	4	3	2
Village diesel generators	19	114	59	92	14	0

Semi-structured interviews held in these communities generally supported the findings of the survey. The most striking feature of household interviews was the strong dissatisfaction among participants at the way the SHS were being maintained. RESCO technicians did visit households once every two months as required, but did not necessarily provide maintenance, often because replacement components such as batteries or light bulbs were not available. In some cases this led households to tamper with their systems (for example through the installation of car batteries to replace non-functioning solar batteries), potentially damaging and reducing the life of SHS.

Interestingly, most households viewed their SHS positively despite maintenance problems. SHS were compared favourably with the previous use of kerosene and batteries for lighting, and households saw particular value for children who could use lighting to complete homework. Several households in Vunivao had purchased their own SHS when Department of Energy systems malfunctioned, and used these systems with inverters for both lighting and appliances. Indeed, a majority of households in Vunivao expressed their willingness to pay more for an SHS if it could power appliances. This was not the case in Nakawakawa, where households are not as embedded in the cash economy and incomes are lower. These findings point to the problems of the 'one size fits all' approach adopted by the RESCO program, as different communities and households are likely to demand and be willing to pay for different levels of power.

6. Discussion: the impact of incentive structures

Problems with the RESCO program at the time of the survey were acknowledged by the Department of Energy, which terminated the contract of the RESCO and awarded it to another private sector company. At the same time, however, it moved ahead with plans to extend the program to other islands in Fiji, in response to strong demand for SHS in those areas. This move reflected the Department's view that the private sector company providing maintenance under the RESCO program was the principal cause of maintenance problems, not the broader RESCO scheme.

6.1. Maintenance under the RESCO program

However, an analysis of the incentives resulting from the RESCO program suggests deeper problems. At first glance, incentives seem sound: the RESCO has incentives to maximise profit by meeting its contractual obligations (providing basic maintenance) at the lowest possible cost, the Department of Energy has incentives to provide replacement components and ensure the RESCO provides basic maintenance, while minimising the level of monitoring required of it, and households have incentives to pay their $14FJ fee and ensure that SHS function correctly. However, this description does not distinguish between the incentives of staff and management within the RESCO and the Department of Energy, or account for information asymmetries within and between these organisations.

Imperfect information and information asymmetries are particularly important, as they can be used to explain incentives under the RESCO program and why these impact on maintenance. In particular, information asymmetries create a number of principal-agent and motivational problems in the administration of the RESCO program. The result is that stakeholder incentives under the program are not always aligned with the task of ensuring that SHS are operational and with sharing information among stakeholders. Information asymmetries are potentially also a source of conflict between key stakeholders, leading to a situation where stakeholders can avoid responsibility for unsatisfactory maintenance by blaming other groups.

6.1.1. Principal-agent problems

Principal-agent situations occur where the incentives and goals of the principal, which directs and benefits from an action (in this case the Department of Energy), differ to those of agents, which are employed to perform the action (in this case the RESCO) [27]. The main causes of principal-agent situations are information asymmetries that exist between the principal and the agent. In most principal-agent situations, agents will have more information relating to their actions than will the principal. Indeed, often the agent is the main source of information for the principal, and will pass on information that is favourable to it. This can impact on the incentives of the agent, where an agent believes it can minimise its work without the principal realising. A range of measures has been created to help overcome principal-agent problems, such as monitoring and penalty provisions in contracts.

The RESCO program displays principal-agent problems between the Department of Energy and the RESCO contracted to provide maintenance. Information asymmetries prevent the Department of Energy from knowing the exact standard of maintenance performed by the RESCO in rural areas, which are often remote. Neither is it always in the interest of the RESCO to reveal this information, as it may suffer financial penalties if it is blamed for the poor performance of SHS. In other words, the process of reporting under the RESCO program is not incentive compatible, as it is not always in the best interests of the RESCO to provide truthful information to the Department of Energy.

This puts the onus on the Department to ensure that the work of the RESCO is monitored. Unfortunately, monitoring systems put in place as part of the RESCO program have not been adequate. Indeed, the contract signed between the Department of Energy and the previous RESCO did not include provisions for monitoring, which was originally done on an informal basis. Monitoring of RESCO maintenance was strengthened in 2008 when the Department installed logbooks in households. These are signed by RESCO technicians when maintenance is performed, and are verified by the Department through spot-checks. However, the penalties that have been placed on the RESCO under this system relate mainly to failure to visit households. The RESCO has not been penalised where SHS are not functional, and to do so would be unfair, potentially penalising the RESCO for delays by the Department in ordering replacement SHS components such as batteries. This is nonetheless important, as it provides the RESCO with perverse incentives to visit all houses (and sign the logbooks), but not to do major work as part of those maintenance visits. The records and discussions with households indicate that this has occurred. The RESCO program therefore fails to align the incentives of the RESCO with its objectives, including: i) ensuring SHS remained functional, and ii) sharing information with the Department of Energy.

6.1.2. Motivational problems

The distinct incentives of staff and management at the RESCO and the Department also need to be considered. Motivational problems are a variant of the principal-agent problem, and affect staff within hierarchical organisations [27]. Again, the main cause of motivational problems is information asymmetries, as staff have better information about work they perform than management. As with the principal-agent situation, the problems is one of incentive compatibility, with employees rewarded for being dishonest rather than truthful about the work they perform. As a result, the incentives of employees are not aligned with those of management, or with completing the tasks assigned to them.

Although difficult to measure, motivational problems affect all hierarchical organisations to some extent. For the RESCO, information asymmetries are likely to exist between management and technicians due to the fact that technicians deal directly with households in isolated areas, often without management supervision. RESCO technicians do not share the same incentives as RESCO management, and do not benefit directly where SHS remain functional. RESCO technicians therefore have incentives to pass on information to RESCO management that is favourable to them, and may avoid work where monitoring by management is weak. Similar problems are likely to affect the Department of Energy. Motivational problems in the Department are probably augmented by understaffing, high staff turnover, and the fact that RESCO related tasks typically form only one of several responsibilities given to employees. This is likely to affect: (i) monitoring of the work of the RESCO, (ii) administration of payments to the RESCO, and (iii) purchasing of SHS components. Interviews with RESCO management indicated that it was unhappy with the performance of the Department in the last two areas. Delays in providing replacement components were also shown to be partly responsible for the long periods that SHS were not functional.

For the RESCO model to function well, information asymmetries need to be overcome, either through improved and more effective monitoring of RESCO activities, or through better aligning the incentives of the RESCO with those of the Department and SHS users. Improving monitoring is a difficult task, given the remote location of SHS, and the very limited resources available to the Department of Energy (discussed in the following section). Nevertheless, the current monitoring system could be modified to avoid generating perverse incentives for the RESCO. More effective monitoring could also alter the incentives of the RESCO, by penalising it where SHS maintenance and reporting is not satisfactory, and rewarding it where it is. A major step in this direction could include linking RESCO payments to the number of SHS that are functional. For this to occur, the issue of delays in component replacement on the part of the Department would first need to be overcome, possibly by moving the role to the RESCO while ensuring accountability is maintained. Given the adverse impact of delays in component replacement on SHS sustainability, this is a worthy goal in itself.

6.2. The policy level

An analysis at the policy level explains why the RESCO program was established in its current form, which differs in several ways to what was originally proposed by donor organisations. In the original proposal, the RESCO was to lease SHS from the Government, and would be responsible for collecting money from users, while setting aside a fixed amount into a Component Replacement Fund. The Department of Energy would still purchase the equipment, using money from the Component Replacement Fund, as this would allow for economies of scale and make equipment cheaper [13,28]. Under that framework, the RESCO had a strong incentive to ensure that SHS worked. Where they did not, households would not pay their fee, but the RESCO would still be required to deposit money into the Component Replacement Fund controlled by the Department of Energy. System failures therefore resulted in financial losses for the RESCO. The tariff charged to users would also have reflected maintenance under the original proposal, and would be negotiated every two years for each service area.

This differs to the scheme currently in place, which has simply extended the arrangements established under the temporary trial that preceded the RESCO program. Under the existing

arrangement, the RESCO has no direct financial incentive to ensure that SHS remain functional, and the $14FJ tariff that has been in place since 2000 fails to cover the full cost of maintenance, which is above $21FJ. The low tariff is also not necessary for affordability. Surveys in 2003 and 2005 found that the majority of households were willing to pay a higher tariff for SHS, so long as they remained operational [12,13].

An explanation for the failure of Government to establish the RESCO program as originally proposed relates to 'ownership'. Ownership issues are frequently observed in aid-recipient relations, where aid is provided to recipients in the expectation they will act in a certain way, only for this not to occur [29,30]. In the case of the RESCO scheme, the original model proposed by the donor was externally designed, with limited Department of Energy input, and was not sufficiently 'owned' by Government of Fiji stakeholders, such as Cabinet and the powerful Ministry of Finance and National Planning. Frequent changes in Government are likely to also have affected ownership. There have been five changes in Government in Fiji (including two coups) since 1998, when the RESCO program was designed. As a result, while successive governments have had political incentives to accept donor aid in the form of SHS that were installed in Vanua Levu, they have not had corresponding incentives to establish the institutional structures advocated by donor groups. This has led to the RESCO program being given a low priority, which can be seen in the Government's failure to pass enabling legislation (drafted by donors) for the RESCO program [23].

The policy level has also had an impact on maintenance under the RESCO scheme in other ways. For example, Fiji Public Service rules under which the Department of Energy operates specify that SHS components must be purchased through the Major Tenders Board, a system that staff argued was bureaucratic and sometimes led to delays of several months (Interviews with Department of Energy staff, 2009). Although this could not explain the full length of delays in maintenance suffered by households with SHS, it was partly responsible. The Departmental budget provided by Government also affects maintenance under the RESCO program. The budget and staff numbers provided to the Department for the administration of the RESCO program are inadequate [23], with the Department's overall budget further reduced in 2010. Indeed, the Department has had to dedicate staff from other areas to ensure that monitoring of RESCO maintenance takes place. Departmental staff that administer the RESCO program also have many other responsibilities and are only able to work part-time on the RESCO program (Interviews with Department of Energy staff, 2009). Departmental staff and management conceded that understaffing partially explains delays in the administration of the RESCO scheme (Interviews with Department of Energy staff and management, 2009).

It is worth noting that the capacity of the Department of Energy to administer the RESCO scheme with its current resources was highlighted as an issue by a consultant in the early stages of the RESCO program [31]. This raises a more general question about the need for Government involvement in administering a program where maintenance is provided by the private sector. The move towards private sector provision of maintenance was motivated in part by the wish to transfer the role away from Government [16,28]. Underlying this were broader economic arguments about the efficiency of private sector as opposed to public sector provision of services, especially infrastructure services. These ideas were strongly promoted at the time by multilateral and bilateral donor agencies, most of which have now moderated their positions [32,33]. Although the impact of these arguments in Fiji and other Pacific island countries was less marked than in regions such as

Latin America, several Fiji Government agencies were nevertheless corporatised and privatised.

In Fiji, not enough attention was paid during this period to the substantial role that Government would need to play to ensure these reforms were a success. This resulted in the failure and eventual reversal of several reforms, and contributed to the lack of continuity in the reform process [34,35]. In the case of the RESCO program the impact was twofold. There was not enough attention paid to the role of the Department in monitoring the RESCO and sourcing components, for which a budget and staff would be needed. As a result, the need to ensure incentive compatibility was not addressed. This was unfortunate, as designing the RESCO program so that stakeholder incentives were aligned with ensuring SHS sustainability could have significantly reduced the level of monitoring of RESCO activities required under the program. The result is that the RESCO program now in place requires extensive monitoring by the Department of Energy, which has not been given sufficient resources to perform the role.

7. Conclusions

Solar home systems (SHS) are a promising technology for rural electrification in developing countries, however high upfront costs and maintenance issues have limited their use to date. Institutional arrangements put in place by governments and donors to overcome these barriers have often failed to ensure that appropriate maintenance of solar systems is provided. This has led to the failure of many solar-based rural electrification projects in the South Pacific.

In Fiji, the Renewable Energy Service Company (RESCO) program is the latest attempt to promote solar-based rural electrification in a fee-for-service model, and is a response to previous problems with community and government provided maintenance and fee collection. This paper presented survey and interview data conducted in two communities, which found significant problems with the maintenance provided under the RESCO program.

Perverse incentives generated by incorrect treatment of principal-agent problems and information asymmetries, as well as motivational problems, can explain this poor maintenance. Most important is the fact that payment of the private sector contractor responsible for maintenance (the RESCO) has been on the basis of households visited under the program, which does not provide the RESCO with incentives to ensure that SHS are functional. The incentives of stakeholders under the program are therefore not incentive compatible, as the RESCO does not have incentives to share information or perform maintenance in accordance with program objectives. The failure to overcome information asymmetries through monitoring or incentive alignment has ultimately led to a situation where no party can be held responsible for poor maintenance, and each has incentives to blame other groups.

The origin of many of these problems can be found at the policy level. Successive governments have failed to implement the RESCO program originally proposed by donors, which would have better achieved incentive compatibility. Governments have also under resourced the Department of Energy, which has adversely affected monitoring of the RESCO and the supply of SHS components such as batteries and light bulbs. These problems can be explained by a lack of ownership and planning with regards the RESCO program by successive governments, made worse by frequent

changes in government.

These experiences point to several lessons for fee-for-service SHS models. First, the incentives of stakeholders must be adequately considered in project design. Second, there are substantial benefits to putting in place institutional arrangements that yield the desired outcomes with minimal ongoing government intervention. This means ensuring incentive compatibility, where the incentives of stakeholders are aligned with program objectives, and stakeholders perform tasks and share information so that those goals are achieved. Incentive compatibility is especially important where government resources are low, making monitoring difficult, as is generally the case in Small Island Developing States. In Fiji, a model where incentives for maintenance were in place for all parties could have substantially reduced the monitoring costs for the Department of Energy. Third, high levels of Government support and ownership are required for a workable fee-for-service SHS model to be established. Clearly this has been lacking in the case of the RESCO model in Fiji.

Current plans to expand the RESCO program to other islands in Fiji are motivated by strong public demand. However, unless the Department of Energy overcomes existing problems with the RESCO scheme, this expansion will be a failure in the long-term. Changes need to be made to the RESCO program so that stakeholders have incentives to perform maintenance and share information, and so that bureaucratic delays in component replacement are overcome. Steps in this direction include: (i) having the RESCO collect money from SHS users directly, and (ii) moving the role of purchasing replacement SHS components from the Department of Energy to the RESCO.

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References

[1] REN21 Renewable Energy Policy Network. Energy for development: the potential role of renewable energy in meeting the millennium development goals. Washington D.C: Worldwatch Institute; 2005.

[2] IAEA. Energy indicators for sustainable development: guidelines and methodologies. Vienna: International Atomic Energy Agency; 2005.

[3] IEA. Towards a sustainable energy future. Paris: International Energy Agency; 2001.

[4] UNDP. Energy and poverty in the Pacific Island countries. Bangkok: United Nations Development Programme; 2007.

[5] Woodruff A. An economic assessment of renewable energy options for rural electrification in

Pacific Island countries. Suva: Secretariat of the Pacific Applied Geoscience Commission; 2007.

[6] World Bank. Technical and economic assessment of grid, mini-grid and offgrid electrification. Washington DC: 2006.

[7] Best G. The role of renewable energy technologies in rural development. In: Bhagavan MR, Karekezi S, editors. Energy for rural development. London: United Nations; 1992.

[8] Wade H. Pacific regional energy assessment 2004: regional overview report. Apia: Pacific Islands Regional Energy Assessment; 2005. South Pacific Regional Environment Programme.

[9] Bugaje IM. Remote area power supply in Nigeria: the prospects of solar energy. Renewable Energy 1999; 18:491-500.

[10] Lemaire X. Fee-for-service companies for rural electrification with photovoltaic systems: the case of Zambia. Energy Sustain Dev 2009; 13:18-23.

[11] Government of Fiji. In: Statistics FIBOS, editor. 2007 census of population; 2007. Suva.

[12] Department of Energy. Rural electrification survey report. Suva: 2006.

[13] Vega L. Financial feasibility and commercial viability of rural sector renewable energy companies in Fiji - prepared for OPRET. Suva: Fiji Department of Energy; 2003.

[14] Nieuwenhout FDJ, van Dijk A, Lasschuit PE, van Roekel G, van Dijk VAP, Hirsch D, et al. Monitoring and evaluation of solar home systems. Amsterdam: Netherlands Energy Research Foundation ECN; 2000.

[15] Nieuwenhout FDJ, van Dijk A, Lasschuit PE, van Roekel G, van Dijk VAP, Hirsch D, et al. Experience with solar home systems in developing countries: a review. Prog Photovoltaics Res Appl 2001; 9:455-74.

[16] Wade H. Survey of RESCO projects e prepared for OPRET, Fiji Department of Energy. 2003.

[17] van der Vleuten F, Stam N, van der Plas R. Putting solar home system programmes into perspective: what lessons are relevant? Energy Policy 2007; 35:1439-51.

[18] Liebenthal A, Mathur S, Wade H. Solar energy: lessons from the Pacific Island experience. Energy Series. Washington D.C: World Bank; 1994.

[19] Bygrave S. Sustainable energy for the environment and development: the diffusion of renewable energy technologies to Pacific Island communities. Centre for Resources and Environmental Studies. Canberra: Australian National University; 1998.

[20] Johnston P, Wade H, Sauturaga M, Vega L, Vos J. Pacific regional energy assessment 2004. Fiji: Pacific Islands Regional Energy Assessment; 2005. Apia: South Pacific Regional Environment Programme.

[21] Jafar M. Renewable energy in the South Pacific e options and constraints. Renewable Energy 2000; 19:305-9.

[22] Outhred H, Healy S, Retnanestri M, Tukunga T. Experience with off-grid photovoltaic systems in Tonga and Indonesia. In: 14th International Photovoltaic Science and Engineering Conference. Bangkok: 2004.

[23] Wade H, Veyan P, Sauvage E, Rowe L. Fiji Islands: large scale RESCO based rural electrification 'proof of concept' project. Transenergie with participation of the Department of Energy. 2006.

[24] Wade H, Johnston P. Pacific regional energy assessment 2004. Kiribati: Pacific Islands Regional Energy Assessment; 2005. Apia: South Pacific Regional Environment Programme.

[25] Gonelevu A. Critical analysis of renewable energy developments (photovoltaic systems). School of electrical, energy and process engineering. Perth: Murdoch University; 2006.

[26] Urmee T, Harries D, Schlapfer A. Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific. Renewable Energy 2009; 34(2):354-7.

[27] Alchian AA, Demsetz H. Production, information costs and economic organization. American Economic Review 1972; 62(5):777-95.

[28] GEF-UNDP. Renewable energy policy development background - prepared for OPRET. Suva: Fiji Department of Energy; 2002.

[29] Ostrom E, Gibson Clark, Shivakumar Sujai, Andersson K. Aid, incentives, and sustainability: an institutional analysis of development cooperation. SIDA studies in evaluation. Stockholm: Swedish International Development Cooperation Agency; 2001.

[30] Ostrom E, Schroeder L, Wynne S. Institutional incentives and sustainable development. Boulder: Westview Press; 1993.

[31] Saupin MG. Establishing of economic framework and incentive policies for renewable energy service companies. Suva: UNDP/GEF; 2003.

[32] World Bank. World Development Report 1994: Infrastructure for Development. Washington DC: 1994.

[33] World Bank. World development report 2004: making services work for poor people. Washington DC: World Bank; 2003.

[34] McMaster J. Public enterprise reform in Fiji: policy implementation and reversals. Asian Journal of Public Administration 2001; 23(2):229-46.

[35] Appana S. New public management and public enterprise restructuring in Fiji. Pacific Studies 2003; 1(1):51-73.