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AGROFORESTRY AND FUELWOOD RESOURCES IN THE PACIFIC ISLANDS: PRESENT STATUS AND FUTURE POTENTIAL

R.R. Thaman 1/

Introduction

Fuelwood is of critical importance to developing countries. The maintenance of fuelwood supplies will, however, be problematic if the agroforestry systems from which much of it comes are not protected and better understood by the international development community. Although wood accounts for only 10% of the total energy used in the world, it provides the major proportion, up to over 90%, of the energy used in poorer countries, particularly among the poorer sectors of society. Even in oil-rich Nigeria, it accounts for over 80% of national energy consumption (C.E.C. c. 1988). Wood, including other forms of biomass, the bulk of which comes from agroforestry systems, is also the main fuel for most rural households and many urban households in the Pacific. However, dwindling reserves of petroleum, the current gulf crisis and resultant price increases in fossil fuels, such as kerosene and liquid propane gas (LPG) have increased the pressure on remaining fuelwood and biomass resources and the agroforestry systems form which they come. As Eckholm (1976) has argued, although dwindling oil reserves and increasing oil prices constitute the "energy crisis" for the developed world, the real energy crisis for a third of the world's people is "a daily scramble the find the wood they need to cook dinner". He stresses that:

(a) their search for wood, once a simple chore and now, as forests recede, a day's labor in some places, has been strangely neglected by diplomats, economists, and the media. But the firewood crisis will be making news -one way, or another -for the rest of the century.

He further stresses that:

(b) at least half of all the timber cut in the world today still serves as fuel for cooking or for heating in colder regions;

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(c) nine-tenths of the people in most poor countries still depend on fuelwood or biomass as their chief source of fuel;

(d) with an average per capita consumption of as much as a tonne of firewood per user per year, population growth is outpacing the growth of new trees; and

(e) "The results are soaring wood prices, a growing drain on incomes and physical energies to satisfy basic fuel needs, a costly diversion of animal manures from food production uses to cooking, and an ecologically disastrous spread of treeless landscapes."

It is ironic that this renewable energy source, that more people rely on than any other fuel, is being depleted more rapidly than the fossil fuels which have been the focus of so much concern in recent years.

Sadly, because of its economic invisibility", most planners, policymakers and aid donors continued to ignore the fuelwood problem until the mid-1970s (C.E.C.c. 1988). They can no longer afford to do so. The vicious circle of fuelwood scarcity, deforestation, environmental destruction and increasing poverty can no longer escape our attention. It, however, can be broken, as it has been in some countries, if policymakers and community leaders recognize the problem and take appropriate action before they "cut off the branch they are sitting on" (Odekoven 1962). In many cases the most appropriate action is to protect or strengthen existing fuelwood systems, both rural and urban, as bases for sustainable household rural and urban energy development. This belief is echoed by the Regional Wood Energy Development Programme in Asia which stresses the importance of traditional agroforestry systems as "one of the major fuelwood production strategies" and the need for agroforestry strategies, rather than conventional forestry approaches", for the "creation of new fuelwood resources" (Wood Energy News, February 1988, Vol.3 No.1). To do so, however, will require a better understanding of both the fuelwood problem an the nature of the existing Pacific island agroforestry systems and environments, the sources of almost all fuelwood.

In this light, the balance of this paper consists of:

(a) a brief summary of the fuelwood energy situation in the Pacific Islands;

(b) a definition of agroforestry, deforestation and agrodeforestation;

(c) a brief discussion of past and present trends of deforestation and agrodeforestation;

(d) an examination of existing Pacific Island agroforestry systems, from which fuelwood demands have been traditionally met and which should be protected and strengthened as the bases for sustainable fuelwood development;

(e) an examination of widespread tree species of Pacific Island agroforestry systems, many of which could play a role in strengthening Pacific island fuelwood systems;

(f) a discussion of the utility of the trees of Pacific Island agroforestry systems; and

(g) suggested strategies for the protection and strengthening of Pacific island rural and urban fuelwood systems, and subsistence incomes, in an effort to free ourselves from the vicious circle of fuelwood scarcity, environmental degradation, dependency and abject poverty that has gripped other areas of the "underdeveloped world".

The Situation In the Pacific

Fr... as a Percentage of Energy Use

In terms of overall energy use (including diesel fuel for electricity generation, fossil fuel for motor vehicle and boat transport, hydroelectric power, etc.), estimates of the proportion made up by fuelwood in various countries were as follows in the early 1980s: P.N.G, Tonga and Kiribati - 66%; Solomon Islands - 62%, Western Samoa - 43%; and Fiji and Vanuatu less than 25%. (FAO 1981 in Holani, 1990). Although the proportions have probably gone down in some areas with increasing urbanization and monetization, overall fuelwood consumption has undoubtedly increased due to population growth and increasing costs of kerosene, liquid propane gas (LPG) and other fuelwood substitutes.

Household Fuelwood Use

The few studies that have been conducted on fuelwood consumption in the Pacific indicate that over 90% of rural Pacific people, and almost an equal proportion of low-income urban people, use fuelwood for most cooking (Siwatibau 1981, Thaman and Ba 1979, Lloyd et al. 1982, Thaman 1985, Sieben 1989, Cheatham 1990). Siwatibau's (1981) study in the late 1970s showed that 92% of 115 rural households in Fiji cooked with wood over an open fireplace. Studies in Tonga and Vanuabalavu in Fiji's Lau group yielded similar estimates, with all households using at least some fuelwood (Thaman and Ba 1979, Thaman, 1985). In the more urbanized Nadi and Lautoka areas of Fiji, where two thirds of all households were electrified (connected to the urban grid system) and three-quarters Indian, 67% of all households used fuelwood always, often or occasionally, and only 29% never used it. Of non-electrified urban households, 83% used wood always, often or occasionally, and only 12% never. In the rural areas covered by the sample, 74% used firewood always or often Lloyd et al. 1982).

Studies in Tonga indicate that 98% of all households use fuelwood for either their daily cooking or their Sunday earth oven (umu) meal (King 1987, Holani 1990); and a 1984 PEDP survey of Tongatapu showed that 94% of rural households used firewood for cooking, with 58% using it exclusively, and that 86% of urban households used fuelwood, with only 26% using it exclusively (PEDP 1985).

On Vaitupu in Tuvalu, all households use fuelwood, including coconut and other biomass residues, with 80% using fuelwood for all cooking (PEDP 1985). On urbanized Funafuti, although 93% of all households used fuelwood, only 12.5 % used it exclusively, with 73.2% using both fuelwood and kerosene Sieben 1988).

In Kiribati, it was estimated that fuelwood and coconut residues accounted for 77% of domestic energy needs on urban South Tarawa and 97% on the outer islands within the Kiribati (Tunggaru) group and 49% of overall energy requirements in the Line and Phoenix groups in 1985 (PEDP 1987); and a 1985 PEDP study showed that fuelwood accounted for 59.6% of total household energy use and 88.6% of energy use for cooking in urban South Tarawa (Cheatham, 1990). Surveys in rural areas of Kiribati Abiang and Tamana), Solomon Islands (Marovo) and Papua New Guinea showed that between 98 to 100% of households use fuelwood (PEDP, 1990).

Institutional Use of Fuelwood

A 1977 Fiji National Food and Nutrition Committee (NFNC) survey of 38 of Fiji's 59 boarding schools showed that 63% still cook exclusively over an open fireplace, with 89% of all schools using wood either exclusively or with other fuels and 67% of urban schools also using wood (Siwatibau 1981). A more recent survey of ten boarding schools in Fiji's Western Division showed that all still used fuelwood exclusively, although a number were now using locally developed improved woodburning stoves (Thaman and Seniloli, 1990). In Tonga, four of five secondary schools depend on fuelwood and coconut waste, at an estimated rate of 250 tonnes/yr, with other institutions such as military barracks, police and maritime training schools, and the prison using fuelwood for cooking (FORTECH 1982, Holani, 1990). The situation is similar elsewhere.

Annual Consumption

In terms of actual consumption, estimates of the average annual per capita consumption in rural areas ranges from 500 kg to one tonne. Siwatibau (1981) found the per capita consumption to be 506 kg (oven-dry weight), of which 353 kg (69.8%) was consumed in home cooking and food preservation, and 151 kg (29.8%) by wood-fired copra driers. Lloyd et al. found the average per capita consumption in the more urbanized and electrified Nadi and Lautoka areas to be about 200kg/year, with more affluent electrified rural users averaging 340kg/year. Brief studies by Siwatibau (1981) of fuelwood use in the Suva-Sawani-Nausori urban and peri-urban area indicate that purchases and foraging from surrounding secondary scrub provide families with an estimated 87 kg/yr, which yields a total estimated national per capita fuelwood consumption of 350 kg/yr for Fiji. Estimates by the Forestry Department and Suva's three main commercial fuelwood suppliers showed that annual wood sales in Suva in the late 1970s to be 716 tonnes, of which 86.3% was burnt in Indian crematoria. Studies in Tonga and Tuvalu estimate per capita daily consumption to be 2 kg, with 2.7 kg being used per household in Tonga for the weekend earthen oven meal (PEDP 1985, Holani, 1990). Estimated consumption in urban Funafuti, Tuvalu in 1988, where only 12.5% of households used only fuelwood and a vast majority used both fuelwood and kerosene, was 10.1 kg per household per week.

Siwatibau's (1981) survey showed that 92% of rural people cooked over an open fireplace, whereas Lloyd et al. (1982) in a sub-sample of wood users, found that 50% cooked over an open fire, 46% on homemade stoves (commonly the Indian chula) and 4% on commercial or other woodburning stoves. The percentage for Tonga was 90% in rural areas and 60 to 70% in urban areas (PEDP 1985). In Tuvalu and Kiribati, most cooking with fuelwood is done over open fires (Sieben, 1988, Cheatham 1990). Unfortunately, the efficiency of cooking over an open fire is very low: about 5 to 10% of biomass energy being converted to useful cooking energy. Moreover, cooking over an open fire poses serious health risks from chronic smoke inhalation (Cheatham, 1990), with studies in India indicating that women suffer extreme exposure to smoke pollution equivalent to smoking 20 packs of 20 cigarettes a day! (Smith, 1985).

Uses of Fuelwood

In terms of the range of uses for fuelwood, after household cooking, the more common uses include:

(a) copra drying;

(b) institutional cooking;

(c) preparation of feasts;

(d) drying or preserving fish and other foodstuffs;

(e) boiling water for clothes and dish washing;

(f) small-scale commercial and subsistence bread baking;

(g) boiling and dying pandanus;

(h) boiling/concentrating toddy syrup (in atoll countries);

(i) cremation (by Indians in Fiji);

(j) charcoal production;

(k) illumination;

(l) heating; and

(m) repelling insects (Siwatibau 1981, Lloyd et al.(1982), Thaman and Ba 1979, Sieben 1988).

In Fiji, for example, 29.8% of a rural person's annual wood consumption in the late 1970s, was used in wood-fired copra driers, drying beche-de-mer, which along with smoking and preserving marine foods, is still an important small-scale commercial activity in many areas of the Pacific, was a major cause of widespread deforestation on small islands last century. Similarly, small local bakeries on Aitutaki in the Cook Islands and in Tonga, use large quantities of fuelwood.

Fuelwood Sources

The vast majority of all fuelwood comes from forests, wildlands and agricultural areas, all of which can be considered part of traditional and evolving Pacific island agroforestry systems. Only in Fiji, Tonga and Papua New Guinea does there seem to be a significant trade in fuelwood or biomass. In rural areas most households acquire fuelwood on their own or from relatives landholdings, whereas in urban and peri-urban areas wood is generally gleaned from houseyard gardens and undeveloped open areas and coastal forests. An increasing number of households in urban and peri-urban areas purchase fuelwood from small- and larger-scale commercial fuelwood dealers, or purchase biomass waste, such as offcuts from timber mills in Fiji and other areas, or coconut shells from the desiccated coconut factory in Tonga. Most boarding schools and other residential institutions cut their own fuelwood from surrounding resources or purchase offcuts or other biomass from timber mills or other sources (Thaman and Seniloli 1990). It must be stressed that, even though an increasing number of institutions purchase fuelwood or biomass, rather than collecting or foraging for it themselves, this wood must still come from existing wildland and agroforestry system resources, in most cases placing increasing pressure on dwindling resources.

Favored Species

In terms of species composition, almost all species are used, in times of need, for fuel. Thus, almost all trees and shrubs constitute fuelwood resources. Where available, generally on the larger high island, high quality fuelwood species such as mangrove (Bruguiera gymnorhiza, Rhizophora spp., Xylocarpus spp. and Lumnitzera littorea), leucaena (Leucaena leucocephala), guava (Psidium guajava), casuarina (Casuarina equisetifolia) and rain tree (Samanea saman or Albizia lebbek), and a range of primarily fallow-land secondary forest species, including Hibiscus tiliaceus, Macaranga spp., Alphitonia spp., Bischofia javanica, Kleinhovia hospita, Rhus taitensis, Grewia crenata are used in preference to other species. In the atoll countries, in coastal areas, and on smaller deforested islands, coconut fuel in the forms of husks, shells and fronds are the most commonly used fuels, with high quality shrub species, such as Pemphis acidula and Suriana maritima constituting important fuel resources. When fuelwood scarcity sets in and preferred species are unavailable, people will burn almost anything including cassava, stalks, cardboard, coconut husks, and twigs and branches of shrubs and small trees, as well as felling valuable food trees such as citrus trees, mango, avocado, Malay apple (Syzygium malaccense) and Tahitian chestnut (Inocarpus fagifer) (Siwatibau 1981, Thaman and Ba 1979, Thaman 1985, Sieben 1988).

Acquisition Strategies

Traditional strategies for fuelwood acquisition include:

(a) collection of natural dead wood/biomass fall;

(b) coppicing, pruning or severely pollarding trees and shrubs, which will regenerate;

(c) using fuelwood and other biomass cleared from new garden areas;

(d) deliberate, but limited, felling of trees and shrubs specifically for fuelwood use; and

(e) use of biomass waste from crops, such as coconut shells and husks, cassava stems and peels, etc.

All of these strategies seemed to fit into the established land use and agroforestry practices of Pacific societies, and, until recently, Pacific peoples have had sufficient fuelwood.

Signs of Fuelwood Scarcity

There are, however, clear signs of firewood scarcity and associated problems of deforestation, soil erosion, the destruction of useful trees, the increasing use of inferior fuelwood species, increasing time devoted to fuelwood acquisition, increasing health risks for women, increasing dependence of easy-to-cook and nutritionally-inferior processed foods, and increasing fuelwood prices and dependence on expensive fossil fuels. There is already serious fuelwood scarcity in urban areas of Papua New Guinea, Honiara, Solomon Islands, and Suva, Fiji, which in PNG has led to indiscriminate predation of existing trees and government fuelwood plantations (King 1987). Fuelwood, particularly, high quality fuelwoods, is in short supply for urban households in the densely populated areas of South Tarawa Kiribati and Funafuti, Tuvalu, where because of increasing demands on scarce resources, partly due to the increasing cost of kerosene, it has been estimated that the biomass resource may be exhausted by 1990 (PEDP, 1985). There is already evidence of a serious firewood famine on the densely populated island of Tongatapu, Tonga

(Thaman 1985; PEDP 1985); and, in rural Fiji, with its extensive areas of primary and secondary forest, fuelwood demands of the growing rural population have already reached the critical stage in some areas (Siwatibau 1981, Thaman, 1979, 1985).

In short, this incipient fuelwood famine seems to be due largely to an almost total failure, on the part of policy makers and the international development community to protect the agroforestry systems and associated wildland resources that have so long provided fuelwood, and an endless range of other subsistence products, to Pacific societies on a relatively sustainable basis. This is partly because most institutionalized government, or aid-funded, rural, agricultural and forestry and "agroforestry" development initiatives have proceeded with little regard for, or little understanding of the role of traditional polycultural agroforestry has played in sustainable development.

Agroforestry, Deforestation and Agrodeforestation Defined

Although the terms agroforestry, social forestry and community forestry are often used almost interchangeably, the term agroforestry will be used here because, in the traditional Pacific island context (although perhaps not in the modern institutional context), the terms are essentially synonymous. There are numerous definitions of "agroforestry". One of the most functionally comprehensive is that of King and Chandler (1978):

(a) Agroforestry is a sustainable land-management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals, simultaneously or sequentially, on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population.

Along similar lines, for the purposes of this paper, "agroforestry" is defined as:

(b) The deliberate incorporation of trees into, or protection of trees within, an agroecosytem in order to ensure its short- and long-term productivity, cultural utility, and ecological stability.

In this context, an agroforestry system" is thus defined as:

(c) Any, agricultural system (agroecosystem) in which planted or protected trees are seen as economically, socially, or ecologically integral to the system.
Deforestation" is defined simply as:

(d) The deliberate and accidental destruction or removal of forests through the use of fire, felling for timber and fuel, overgrazing, clearance or destruction for agricultural and urban-industrial expansion, and other human activities.

Related to, but often lumped in with, deforestation is the process of "forest degradation", a very widespread problem in the Pacific, where forest is not strictly removed, but only degraded through the removal or destruction of trees or degradation of forest environments and associated plant and animal species. Forest degradation is usually the most common result of selective and often uncontrolled logging of Pacific forests.

Finally the term, "agrodeforestation" (Thaman, 1988bc, 1989a) is introduced and defined as :

(e) The removal of trees or the de-emphasis on planting and/or protection of trees in the context of existing agroecosystems.

These rather unrestrictive and functional definitions have been selected to cater for the great diversity and functional utility of existing Pacific Island agroforestry/agricultural systems, which range from dooryard or houseyard and squatter-garden agroforestry in both urban and rural areas to deliberate intercropping and the protection of trees and tree-like perennials in garden areas and the planting of woodlots and protection of inland and coastal forest stands in sparsely populated rural areas. Emphasis is placed on the understanding of the roles that specified agroforestry systems, particularly traditional or existing ones, and their component trees play and could continue to play in sustained-yield fuelwood development and the provision of subsistence incomes in the Pacific islands.

As suggested above, almost all fuelwood originates from Pacific island rural or urban agroforestry systems. Their destruction or degradation, thus, affects any fuelwood development strategy, and, in a sense, an energy crisis for Pacific peoples.

Deforestation and Agrodeforestation in the Pacific

Deforestation and the Environmental and Cultural Consequences

It should be stressed that although traditional agroforestry systems seem relatively sustainable and conservative compared to the more exploitative monocultural agricultural, forestry and agroforestry systems of today, there is widespread evidence that Pacific people also abused their traditional agroforestry systems and probably suffered from fuelwood famines prior to European contact and the coming of "development". This has, of course, accelerated with post-European-contact modernization.

Throughout the Pacific, deforestation and subsequent repeated burning have been responsible for the evolution of fire-climax forests, grassland savannas, and degraded fern and scrub lands. Such a process has undoubtedly been the main cause of the extensive anthropogenic grasslands of highland New Guinea, the xerophytic niaouli (Melaleuca leucadendra) savanna lands of New Caledonia, the highly degraded "sunburnt lands", or talasiga, found throughout Fiji, and the rapidly expanding saafa (Panicum maximum) grasslands of Tongatapu in Tonga.

Deforestation has led to severe erosion in Wallis and Futuna, the Cook Islands, French Polynesia and Hawaii where most of the indigenous forest has been removed, leaving degraded fernlands and grasslands no longer suitable for agriculture (Kirch 1982:4). Flenley and King (1984) go as far as suggesting that deforestation was responsible for the collapse of the pre-european megalithic culture on Easter Island, a view supported by McCoy (1976 in Kirch 1982:4), who argues that the radical reduction of forest, shrub, and grassland communities, following over-exploitation and misuse by man" was responsible for a change from open-field cultivation to protected stone garden enclosures (manavai). Similarly, drastic deforestation of the central plateau on the Hawaiian island of Kaho'olawe, due to shifting cultivation and increasing population pressure between AD 1375 and 1600, reportedly led to a "dramatic population crash" and the total abandonment of the interior of the island by 1700 (Hammon 1980, Kirch 1982:4).

More recently, the removal of coastal strand species and mangroves for fuelwood occurs in many areas and has led to accelerated coastal erosion (Thaman and Ba 1980). The reported removal of mangrove forest in Tonga's Ha'apai group to eliminate mosquito breeding sites (at the wish of a WHO expert") may have led to the loss of a village's entire coastal frontage during a subsequent storm (Thaman and Clarke 1987). In perhaps the most extreme case, by the turn of the century, the entire indigenous forest and most of the coastal strand forest of the 24 km^2 island of Nauru will have been transformed into a virtually unusable moonscape by 80 years of open-cast phosphate mining and associated urbanization (Manner et al. 1984, 1985). It is ironic that high-quality fuelwood species such as Calophyllum inophyllum are piled and burned as rubbish on Nauru to clear the way for phosphate mining to help trees grow in Australia and New Zealand.

Although large stands of economically and ecologically precious tropical forest remain on some of the larger islands, and small areas of mangrove and ubiquitous coastal strand forest have been preserved on others, deforestation in the Pacific is proceeding at a frightening rate. Forests, both primary and secondary, continue to be transformed into degraded savannas and fern grasslands, mangroves into housing and industrial estates or other lifeless land-sea interfaces, and polycultural tree-studded traditional agroforested gardens into monocultural plantations. Urban areas are divested of their remaining trees to make way for industrial, commercial, and residential areas or to fuel the cooking fires or erect the squatter housing of low-income families. The trends are the same from the high continental islands of Melanesia to the smallest atoll islets of Polynesia and Micronesia (Thaman and Clarke 1987).

Agrodeforestation as an Issue

Although deforestation and forest degradation, have received most attention, probably of tantamount importance, particularly in relation to the depletion of accessible fuelwood resources, is "agrodeforestation" in the forms of declining tree planting and the elimination of trees from agricultural and urban landscapes.

The "Green Revolution", held to be the panacea for expanding world food production, has, in addition to its proven social flaws, led to serious agrodeforestation. Based on a universalist and diffusionist philosophy of development which places too much emphasis on the virtues of transfers of technology and the widespread use of 'miracle' varieties of wheat and rice (Sachs,1976:51), the Green Revolution has led to the reduction of genetic variety and widespread elimination of trees in rice-growing areas. Recent studies of the remarkable strides China has made in solving its food production problems, for example, indicate that China's modern agricultural policies, particularly those aimed at bringing marginal lands into production using Green Revolution technology, have been environmentally disastrous and led to widespread deforestation and agrodeforestation. As a result, serious problems of wind and water erosion, sedimentation, salinisation, desiccation, as well as contamination of shrinking water supplies have beset China (Vermeer,1984:6). On Hainan Island, for example, the ecological balance has been seriously disturbed by the indiscriminate destruction of trees since the 1950s, mainly due to the policy of grain growing as the key to agricultural development, the use of primitive slash-and-burn methods, the expansion of estate farms, and the lack of coal which has led to the use of wood as a fuel. As a result, the natural forest of Hainan and its rich diversity of plant and tree species and timber, fuel and medicinal plants, decreased from 863,000 to 245,000 hectares between 1954 and 1980 (Vermeer,1984:10).

Similar trends are widespread in the Pacific Islands, where increasing emphasis on monocropping, primarily for export, but also to satisfy rapidly growing local urban markets, has led to the felling and uprooting of a wide range of environmentally, culturally and nutritionally important trees to make way for the plough or for monocultural stands of export crops. Coupled with this is the widespread failure of younger farmers, to replant or protect the trees which have always been integral components of their parents' traditional agroforestry systems.

The situation is particularly serious on smaller islands and atolls with little or no remaining native forest, where agricultural areas and houseyard gardens serve as the few remaining reserves where endangered plant varieties or cultivars can be protected. In Tonga, for example, during the height of the banana boom of the late 1960s, so many trees in agricultural areas including mango, citrus, and a wide range of medicinal, fuelwood, and handicraft species) were cut to provide shooks for banana boxes and to extend banana plantings, that sawmillers had to move from Tongatapu to the nearby island of 'Eua (Thaman 1976).

Most of the trees that, today, provide food, timber, firewood, medicines, or serve other cultural and ecological functions in Pacific agroecosystems have been planted or protected by past generations. Sadly, many of these trees are not being replaced or protected by a present generation that commonly knows neither the vernacular names, nor the uses of such species. Buying kerosene or LPG, opening a tin of imported peaches for a feast, going to the local dispensary or pharmacy for medicines, or purchasing imported plastic flowers, perfumes, and deodorants have replaced the products that depended on the planting or protection of trees as integral components of agricultural systems and houseyard gardens in the past.

Although some countries have increasingly effective systems of forestry reserves, conservation areas, or national parks, few, if any, have legislation or programmes prohibiting the cutting or promoting the replanting of endangered tree species as part of modern institutionalized agricultural development. Thus, agrodeforestation continues, with little or no official recognition and, therefore, few attempts to reverse the trend Thaman 1989a).

Nature of Traditional Agroforestry

To understand the potential of traditional agroforestry as a basis for sustainable fuelwood development, it is necessary to understand the nature of the diverse traditional systems that existed from the isolated highlands and malarial swamps of Papua New Guinea in Melanesia to the smallest atolls of Polynesia and Micronesia, and which have always been central to the economic, social and ecological wellbeing of Pacific people.

In traditional Pacific Island societies, aspects of living such as energy provision, forestry, agriculture, housing, medicine, and trade and industry were not compartmentalized into economic "sectors" as they are in modern development. Rather, they were integral components of agroforestry systems tailored to the environmental and societal needs of each island ecosystem. Although modern agroforesters and horticulturalists may see native forests, agroforestry systems, and trees in terms of their economic value, or, possibly, even in terms of their ecological, recreational, aesthetic, nutritional or biomass values, Pacific Island agroforesters perceived arboreal resources to be far more multi-purposeful (Thaman and Clarke 1990a).

The disadvantages of trees as seen by modern developers (for example, taking up too much field space or the lag-time between planting and maturity), which have often led to their domination or replacement by more immediately productive annuals, should rather be seen as advantages in a world where biological stability is increasingly precarious. Trees also provide other benefits: low labor requirements for maintenance compared with annuals; provision of the "insurance" of reserve food and fuel supplies, should annauls crops or overseas imports become unavailable; and, in combination with annuals, aggregate yields greater than many monocultures. Of particular importance in the Pacific, given the widely-documented rapid increases in nutrition-related diseases and dangerous levels of food and fuel dependency, is the contribution of agroforestry systems to dietary diversity and sustainable local food and energy production (Thaman and Clarke 1990a).

Diversity of Systems

There is great diversity in Pacific-island agroforestry systems, none exactly alike in species composition or technologies or strategies employed. All have been adapted to the social, economic, and ecological conditions and limitations of a given area, and all have a range of favorable characteristics and constituent tree species that make them excellent bases for sustainable future development, and, in particular, fuelwood or biomass development. These existing systems range from the extensive agroforestry systems in areas of low population density in Melanesia to the highly intensive systems characteristic of the smaller islands and atolls of Polynesia and Micronesia and of modern urban areas.

In areas of low population density, extensive shifting agroforestry systems constitute an "agriculturalization of the forest" (Clarke, 1971). Although there is variation in practice from place to place, the basic strategy consists of felling or ringbarking certain species of trees and clearing the underbrush, usually through burning, from a section of fallow land, while at the same time protecting selected tree species, which will remain or be allowed to regenerate along with deliberately planted short-term and long-term ground and tree crops.

Trees that have been preserved, usually slow-growth forest, fruit or nut trees, and trees of medicinal or other cultural importance, are often pruned or pollarded to open up garden areas to sunlight and to add additional organic material to the soil and to provide fuelwood. Selective weeding during the life of gardens protects important pioneer species, which will dominate early stages of the fallow vegetation. Domesticated trees are also often planted, so that, as gardens age, orchards are initiated and come to be scattered widely throughout fallow areas and provide a valuable supply of materials and foods for years to come. As they age over several decades, the orchards merge back into secondary forest, which again becomes available for clearing for new gardens and use as fuel.

Although shifting agroforestry is the dominant land use, most societies have a range of distinct agroforestry zones, depending on the nature of the land, population densities, and the location of settlements. These include village or houseyard gardens, permanent village tree groves, coastal and inland gardens (some very permanent), fallow areas, including mature fallow forest, and distinct areas of primary or relatively undisturbed secondary forest and old-growth fallow forest, as well as sections of coastal strand or mangrove forest which serve as hunting reserves and sources of medicines, fuel and other products. Trees in all zones provide a matrix for ground cropping, grazing, and residences, and supply a wide range of wild food, fuel and other non-food resources.

Species diversity is considerable in all systems, with Melanesian agroforestry systems characteristically having more than one hundred tree or tree-like species, almost all of which are, or can be used as fuel. In the approximate order of their agroforestry importance or abundance, they include widely-cultivated food and non-food species, species that are protected or preserved when clearing garden areas, and species that are protected upon spontaneous generation. For many species, both wild or feral and cultivated forms are recognized. The more common domesticated species are usually represented by many cultivars or varieties. The wide range of husbandry and selection strategies includes deliberate planting of seeds, shoots, branches and other vegetative parts, the transplanting of self-sown seedlings, and the protection of seedlings in fallow vegetation.

All agricultural and land use zones have major arboreal components. The main species found in villages and houseyard gardens, in permanent village tree groves, and as protected or deliberately planted intercrops in food gardens include coconut palms, a wide range of banana and plantain cultivars, breadfruit, sago palm, nut trees (Canarium spp., Barringtonia edulis, Inocarpus fagifer, and Terminalia catappa), Burkella obovata edible pandanus (Pandanus spp.), Malay or mountain apple (Syzygium malaccense), oceanic lychee (Pometia pinnata), Polynesian vi-apple (Spondius dulcis), Gnetum gnemon, edible figs (Ficus spp.), Dracontomelon vitiense, Adenanthera pavonina, and a number of palms including the betelnut (Areca catechu) and Prichardia and Veitchia spp. Other less common or locally important species found planted or protected in gardens and tree groves include Antiaris toxicaria, Sterculia sp., Semecarpus sp., and Corynocarpus cribbeanus. All provide burnable biomass.

In most coastal areas, and particularly on atolls, the coconut is ubiquitous within gardens and areas under short-term fallow. In more mature fallow areas, the coconut is often dominant, with other useful trees scattered amongst coconut palms in poorly maintained copra plantations. Whereas in coconut "plantations", palms tend to be evenly spaced and of a similar age class, the palms in food gardens and fallow areas tend to be randomly scattered and of different age classes. It is under the harsh environmental conditions of atolls, with their paucity of flora, that the coconut palm achieves its greatest importance, forming a coconut forest that shelters food crops, ocean-dispersed coastal trees, and villages or settlements, and constitutes by far the most important renewable fuelwood resource (Thaman 1990a).

Also important, particularly in the areas near villages, are species commonly planted as living fences, hedges, or pig pens. These include Casuarina equisetifolia, Erythrina variegata, Glricidia sepium, Hibiscus rosa-sinensis, Hibiscus tiliaceus, Leucaena leucocephala, Pterocarpus indicus, Polyscias spp., Dilennia biflora, Pemna serratifolia, and Jatropha curcus, most of which are commonly pruned or coppiced to provide fuel.

Throughout the Pacific, considerable emphasis is also placed on the protection and extension of strand vegetation, with the planting of genera such as Pandanus, Barringtonia, and Terminalia, and species such as Calophyllum inophyllum, Casuarina equisetifolia, Cerbera manghas, Gyrocarpus americanus, Hernandia nymphaeaefolia, Hibiscus tiliaceus, Neisosperma oppositifolia, Pemphis acidula, Premna serratifolia, Pipturus argenteus, and Scaevola sericea and Suriana maritima, some of which are semi-domesticated species planted in inland gardens, tree groves, and houseyard gardens.

The dominant staple ground crops in most traditional shifting systems are yams and Colocasia taro, although other ground and tree crops, particularly bananas and plantain cultivars, are also planted, with sweet potato, cassava, and Xanthosoma taro of major importance in some areas, especially where agricultural intensification and agrodeforestation are taking place. There is also a diversity of other ground crops including sugar cane, Saccharum edule, hibiscus spinach (Hibiscus manihot), Alocasia taro, pumpkin, pineapple, maize, chili peppers, cabbages, beans, and non-food species such as kava (Piper methysicum), Pandanus spp., paper mulberry (Brousonnetia papyrifera), and tobacco. The more stabilized, essentially permanent cultivation of wetland taros (Colocasia esculenta and Cyrtosperma chamissonis) was practiced on most high islands, using systems of walled gardens, irrigated and dryland terraces, and pits excavated to the water table on atolls and coastal areas. Sophisticated mulching systems using the leaves of trees, grass, other plant debris, seaweeds, pumice and even tin cans are common, particularly on soil-poor atolls.

The polycultural mix of trees and tubers and fruit- or leaf-bearing crops provides a fairly good diet that is complemented by domesticated pigs and fowl, fish, eels, insect larvae, birds, fruit bats, and other wild game, and a range of wild plant foods, such as wild yams, ferns, nuts, fruits, and greens from the surrounding forests, fallow areas, rivers, and swamps. In coastal areas, and particularly on atolls, reef gleaning and a wide array of fishing techniques provide an abundance of protein.

Where population densities are low, garden plots may be abandoned to forest fallow after only one crop of yams or taro, with fallow periods ranging from ten to over twenty years. Correspondingly longer cropping periods and shorter fallow periods are characteristic on richer alluvial and colluvial soils, in more accessible gardens nearer villages, and areas where population densities are high. In areas of increasing population density and pressure on land, often due to expanded export cash cropping and commercial livestock development, or in locations closer to settlements, the areas of primary forest decreases, secondary forest is younger and floristically less complex, and large areas are covered by almost pure stands of scrub, small trees, and degraded grasslands. As cropping cycles are extended and fallow periods shortened, orchards in maturing fallow vegetation also become increasingly rare, and game and wild plant foods more scarce.

With the growth of towns and cities and the official emphasis on commercial monocropping and industrial forestry at the expense of polycultural subsistence agroforestry, urban agroforestry and houseyard agroforestry in rural and peri-urban areas become increasingly important. Houseyard gardens incorporate a wide range of food trees, non-tree staple and supplementary food plants, fuelwood plants and non-food plants of considerable technological, economic, social, ecological, and ornamental value.

Institutionalized, government-supported agroforestry, in contrast to traditional agroforestry, focusses primarily on generating employment and export earnings. Secondarily, projects may be intended to meet demands for forest products or to reduce adverse environmental impacts of deforestation. A recent emphasis of "agroforestry" programmes has been increased productivity through multiple use, which is often narrowly defined in terms of multiple production of timber species along with commercial crops or livestock. Such activities fall into three basic categories:

(a) intercropping of commercial tree crops with ground or tree crops;

(b) planting of exotic timber and/or fuelwood species in existing agricultural systems, as intercrops, rotational crops, alley crops or as small-scale monocultures or woodlots; and

(c) grazing under commercial tree cropping or silvicultures.

The predominant emphasis of most activities is not on small-scale community polycultural agroforestry or social forestry. Consequently, most indigenous species and the wide range of traditional cultivars and fuelwood species have received little official promotion, have been the focus of only limited research, and have had few if any technical experts or development entrepreneurs who have enough knowledge about traditional mixed agricultural systems and their species to promote them. More often than not, traditional agroforestry and fuelwood systems have been degraded, displaced, or eliminated in the name of institutionalized "modern" agricultural, forestry, or, more recently, "agroforestry" and even biomass plantation development.

Trees of Pacific Island Agroforestry Systems

By definition, it is the trees and tree-like species of Pacific agricultural and horticultural systems which make them "agroforestry systems" (rather than merely agricultural systems), and which must be preserved and considered first as the basis for future agroforestry development and in the reversal of current trends of deforestation and agrodeforestation.

Selection and Reselection of Agroforestry Resources

Whether on high islands, with their rich soils, varied habitats, and low population densities, on the harsh almost soil-less atolls, or in home gardens in densely settled urban areas and monocultural rural agricultural areas, all Pacific societies have selected and re-selected, in relation to their particular environmental and cultural needs, a wide range of tree- and tree-like species for incorporation into their agroforestry systems. Thaman (1990b) has identified at least 419 cultivated and/or wild tree or tree-like species or groups of closely related species of widespread or local economic, cultural, and ecological importance in Pacific Island rural and urban agroforestry systems.

These species are the cumulative result of a selection process which has occurred over thousands of years, beginning almost certainly in the ancestral homelands of today's Pacific islanders in Southeast Asia and the archipelagic areas of Indonesia, Philippines and Papua New Guinea, from where valuable cultigens and accumulated knowledge and uses of widespread indigenous species and genera were transferred to the smaller Pacific oceanic islands.

Subsequent to arrival, new indigenous species that were encountered in the islands were incorporated into Pacific agroforestry systems prior to European contact. Similarly, appropriate post-european-contact introductions, including food plants, timber trees, fuelwood species, ornamental plants, and other trees, tree-like species, and distinct cultivars have been tested, selected, reselected and incorporated into today's systems, to such an extent that the undiscerning visitor or agricultural "expert", and many of the current generation of islanders, believe them to be traditional or even indigenous, so much so that the status of many species remains unclear as to whether they are indeed indigenous, aboriginal introductions brought to the islands because of their cultural importance by successive waves of Pacific settlers, or early post-european contact introductions.

Nature of Agroforestry Species

Of the 419 tree or tree-like species or distinct cultivars of widespread or localized agroforestry importance described by Thaman (1990b), approximately 329 are classified as large or small tree or tree-like species (in terms of height), whereas approximately 90 are smaller more shrub-like perennials, which constitute relatively permanent fixtures in Pacific island agroforestry systems. The classification system is, of course, somewhat arbitrary because some species, depending on the environment, the variety, or cultivar, can be either shrubby or tree-like. For example the species Hibiscus tiliaceus, Pipturus argenteus and Vitex trifolia are all found as both "shrubs and trees". Similarly, groups of highly variable closely related species of the genera Leucosyke, Pandanus, Pittposporum, Psychotria, Solanum, and Timonius are all represented by both shrubs and trees.

Shrubs and Shrub-like Species

The 90 shrub-like species include indigenous species such as Acalypha insulana, Allophylus timoriensis, Alpinia spp. Caesalpinia bondoc, Clerodendrum inerme, Colubrina asiatica, Decaspermum fruticosum, Desmodium umbellatum, Dodonea viscosa, Geniostoma spp., Melastoma malabathricum, Pemphis acidula, Scaevola sericea, Sida fallax, Suriana maritima, Ximenia americana, and species of the widespread and variable genera Alyxia, Canthium, Crytandra, Euodia, Geniostoma, Ixora, Jasminum, Phaleria, Timonius and Wikstroemia which are commonly found in either a protected state in, or around active garden areas in patches of wild or fallow vegetation.

Also in the "shrub" category are important food or beverage plants, including the pigeon pea (Cajanus cajan), of particular dietary importance to Fiji's Indian community and in Guam; the ubiquitous perennial chili pepper or tabasco (Capsicum frutescens); bush hibiscus spinach (Hibiscus manihot); sugarcane (Saccharum officinarum), which forms tree-like stands in traditional Pacific island agroforestry systems; edible sugar cane inflorescence (Saccharum edule); kava (Piper methysticum), the important social beverage of Vanuatu, Fiji, Polynesia, and Pohnpei; betel pepper (Piper betel), which is cultivated in Western Melanesia, high-island Micronesia, and by the Indian community of Fiji; curry leaf (Murraya koenigii), pomegranate (Punica granatum), which are common in Indian gardens in Fiji and occasional in some other areas; and the eggplant (Solanum melongena), which is particularly important in Fiji, but which is grown throughout the Pacific.

Coffee, in particular Arabian and robusta coffee (Coffee arabica and C. canephora), are important small holder commercial export crops in Papua New Guinea, New Caledonia, Vanuatu, and Hawaii, and is also grown to a limited extent in Tonga, Samoa, the Cook Islands, Tahiti, and some other islands. Tea (Camellia sinensis) is an important export crop in areas of the Papua New Guinea highlands and has been introduced elsewhere.

Shrubby handicraft plants of a widespread importance include paper mulberry (Broussonetia papyrifera), of major importance from the highlands of Papua New Guinea, where it is used in the production of string bags (bilum) and a wide array of lion cloths and other attire, to Polynesia where it is used in the production of the ceremonially-important tapa cloth, an increasingly important source of cash income from the tourist industry; and a wide variety of

Pandanus species or cultivars which are used in plaited ware such as fine mats, thatching, hats, baskets and other items of ubiquitous cultural and economic importance.

Alyxia spp., Coleus scutellariodes, Cordyline fruticosa, Euodia hortensis, Cestrum nocturnum, Gardenia taitensis, and G. jasminoides, Ixora spp., Jasminum sambac and Murraya paniculata are all shrubs, shrubby vines or small trees grown (collected from wild plants in the case of Alyxia spp.) for their fragrant and colorful flowers and leaves which are used in garlands and other body ornamentation and/or for scenting coconut oil, while other species, such as Acacia farnesiana, Alpinia spp., Bougainvillea spp., Calliandra spp., Cassia alata, Cestrum diurnum and C. nocturnum, Codiaeum variegatum, Dracaena fragrans, Euphorbia pulcherrima, Ficus elastica, Jatropha hastata, Lagerstroemia indica, Lantana camara, Nerium oleander, Tecoma stans and Thevetia peruviana, are increasingly important ornamentals, the flowers of which are occasionally used in body ornamentation.

Of particular importance are the shrub-like hedge panaxes, including Polyscias balfouriana, P. filicifolia P. fruticosa, P. gulfoylei, P. scutelleria and P. trichochleata, which are planted as living hedges throughout the Pacific, with the young leaves of some species being occasionally eaten with pork in Melanesia. Other important ornamental hedgeplants include the widely used Acalypha amentacea (A. wilkesiana) and Hibiscus rosa-sinesis.

"Protective" or magical plants, planted in, or around active garden areas to ward off evil spirits, include Cordyline fruticosa, Coleus scutellariodes, and Euphorbia fidgiana, the latter seems to be reported only from Fiji and Tonga.

The physic-nut (Jatropha curcas) is a common living fence species and a nurse plant for vanilla in Tonga and Fiji. Tecoma stans serves the same purpose in Tahiti. The castor bean (Ricinus communis) is found both naturalized and cultivated throughout the Pacific, and Acacia farnesiana is locally important in Nauru, Kiribati and the dry zones of the main islands of Fiji. Derris root, a source of rotenone (Derris spp.) is a commonly protected and occasionally planted shrubby vine for use (although now often illegal) as a fish poison.

Piper aduncum is a locally important fuelwood plant, which is protected and coppiced in agricultural areas in Fiji. A number of fast-growing species of Acacia and Calliandra have been successfully planted as potential sources of fuelwood in Fiji.

Trees and Tree-like species and Cultivars

The specific nature of the 329 larger tree, tree-like species or groups of variable tree species will be covered in detail in the following sections. Although technically grasses, the bamboo species, Bambusa vulgaris, Bambusa spp. and Schizostachyum glaucifolum, all important fuelwood species, are classified as "trees", as are a range of giant tree-ferns (Cyathea spp.), the cycad (Cycas circinalis), and a wide range of banana and plantain species or cultivars, which, although tree-like, are really giant herbs.

Antiquity Status

Of the 419 species, 172 are probably indigenous to most islands where they are found, 13 are probably aboriginal introductions, 40 either indigenous of aboriginal introductions, 147 "recent" post-European contact introductions, 17 indigenous in some areas but recent introductions in other areas, 17 both aboriginal or recent depending on the area, and 13 indigenous, aboriginal or recent depending on the area (Table 1). It is, however, extremely difficult to determine whether some species were indigenous or introduced by indigenous settlers. The dual or trial status for many species is due to the fact that either the true antiquity status is uncertain and masked by antiquity, or that the status may be different for different species in different areas, e.g., Terminalia catappa may be both indigenous and/or an aboriginal introduction to some areas, whereas it is probably a recent introduction into Hawaii.

Table 1 shows the antiquity status of 419 widespread or locally important tree or tree like species. 2/

Table 1 3/

Antiquity Status

Antiquity Status	Number
Indigenous	172
Aboriginal Introductions	13
Indigenous or Aboriginal Introductions	41*
Recent Post-european-contact Introductions	147
Indigenous or Recent Introductions	17
Aboriginal or Recent Introductions	17
Indigenous, Aboriginal or Recent Introduction	13
Total	420*

Indigenous Species

The 172 possibly indigenous species include ubiquitous Pacific island coastal strand forest, mangrove forest, and marsh or riparian species, which are important components of plots of relatively undisturbed vegetation bordering or included in agroforestry systems and/or which are deliberately protected or planted as integral components of rural gardens or plantations and urban gardens because of their cultural and ecological utility. The coastal strand species include Acacia simplex, Allophyllus timorensis, Barringtonia asiatica, Calophyllum inophyllum, Casuarina equisetifolla, Cerbera manghas, Clerodendrum inerme, Colubrina asiatica, Cordia subcordata, Desmodium umbellatum, Dodonea viscosa, Erythrina variegata var. orientalis, Ficus spp., Gardenia taitensis, Grewia crenata, Guettarda speciosa, Gyrocarpus americanus, Hernandia nymphaeaefolia, Hibiscus tiliaceus, Intsia bijuga, Morinda citrifolia, Neisosperma oppositifolia, Ochrosia elliptica, Pandanus tectorius, Pemphis acidula, Phaleria spp., Pipturus argenteus, Pisonia grandis, Planchonella costata, Pongamia pinnata, Premna serratifolia, Scaevola sericea, Sida fallax, Terminalia catappa, T. littoralis, Thespesia populnea, Tournefortia argentea, Vitex spp., Wikstroemia spp. and Ximenia americana.

2/ The total of 420* reflects the inclusion of two distinct varieties of Erythrina variegata, one of indigenous or aboriginal status (41*) and the other of recent origin.

3/ The dual or trial status for many species is due to the fact that either the true antiquity status is uncertain or that the status may be different for different groups.

Heritiera littoralis, Lumitzera littorea, Rhizophora spp., Sonneratia alba, and Xylocarpus spp., while common coastal swampland or riparian species include the sago palm (Metroxylon spp.), the Tahitian chestnut (Inocarpus fagifer), and Barringtonia racemosa.

Indigenous coastal lowland and montane forest species (some of which are occasionally also present in coastal strand vegetation), which are also seen as important components of agroforestry systems, include the variable but widespread species of the genera Acacia, Acalypha, Agathis, Aglaia, Alphitonia, Alstonia, Alyxia, Antidesma, Araucaria, Astronidium, Barringtonia, Boerlagiodendron, Breynia, Buchanania, Burkella, Calophyllum, Canarium, Canthium, Casearia, Celtis, Cinnamomum, Claoxylon, Croton, Cryrtocaria, Cyathocalyx, Cyrtandra, Dendrocnide, Dillenia, Diospyros, Dolicholobium, Dysoxylum, Elaeocarpus, Endospermum, Ervatamia, Euodia, Ficus, Garcinia, Gardenia, Geissos, Geniostoma, Glochidion, Gmelina, Guioa, Halfordia, Hedycarya, Homalanthus, Homalium, Horsfieldia, Ixora, Jasminum, Leea, Leucosyke, Linociera, Litsia, Macaranga, Maesa, Mallotus, Maniltoa, Maoutia, Melicope, Melochia, Metrosideros, Mimusops, Morinda, Mussaenda, Myristica, Nauclea, Neonauclea, Neubergia, Palaquium, Phaleria, Phyllanthus, Pittosporum, Planchonella, Polyalthia, Polyscias, Psychotria, Randia, Santalum, Sauraria, Semecarpus, Sterculia, Syzygium, Tarenna, Terminalia, Timonius, Vavaea, Weinmannia and Xylosma. Less variable species, some of which are only locally important, include Baccaurea seemanii, Campnosperma breviopetiolata, Commersonia bartramia, Decaspermum fruticosum, Dodonea viscosa, Elattostachys falcata, Ervatamia orientalis, Flacourtia rukum, Garuga floribunda, Gironniera celtidifolia, Gnetom gnemon, Grewia crenata, Hernandia moerenhoutiana, Kleinhovia hospita, Mammea odoratus, Manilkara dissecta, Maoutia australis, Melaeuca leucadendra, Micromelum minutum, Neubergia corynocarpa, Parinari glaberrima, P. insularum, Pleiogynium timoriense, Pterocarpus indicus, Readea membranacea, Rhus taitensis, Securinega flexuosa, Trema orientalis, and Vavaea amicorum.

Of these, Acalypha spp., Alphitonia zizphoides, Alstonia scholaris, Antidesma spp., Commersonia bartramia, Dysoxylum spp., Dodonea viscosa, Ficus spp., Glochidion spp., Ervatamia orientalis, Grewia crenata, Homalanthus spp. Kleinhovia hospita, Leucosyke spp., Macaranga spp., Melochia spp., Micromelum minutum, Morinda citrifolia, Pipturus argenteus, Pittosporum arborescens, Rhus taitensis, Syzygium spp., Tarenna sambucina, Trema orientalis, Vavacea amicorum, and Xylosma spp. are widespread pioneer species of considerable importance in secondary forests and fallow vegetation. The ubiquitous coastal strand and riparian species Hibiscus tiliaceus is also widespread in recent secondary forests and disturbed sites, and, along with the other secondary species, is commonly encouraged through selective weeding and protected once established.

Almost all of these species are used as fuelwood, some of them being considered among the most desireable species.

Aboriginal Introductions

It must be stressed, however, that although many of these species seem to be definitely native to some areas, some, such as Acalypha spp., Aglaia saltatorum, Alyxia spp., Barringtonia spp., Ficus spp., and Parinari spp. could have been deliberately introduced prior to European contact to some islands because of their considerable cultural importance.

Of the some 83 species which were possibly aboriginal introductions, to at least some islands, the most widespread and culturally important species are food plants, including the ubiquitous Pacific island "tree-of-life", the coconut palm (Cocos nucifera), the breadfruits

(Artocarpus altilis and A. mariannesis), the vast range of traditional banana and plantain cultivars (Musa cultivars), including the mountain banana or fe'i (Musa troglodytarum), edible pandanus cultivars (Pandanus dubius and Pandanus spp.), sugarcane (Saccharum officinarum), edible sugarcane inflorescence (Saccharum edule), bush hibiscus spinach (Hibiscus manihot), the formerly more important food and sugar plant (Cordyline fruticosa), and the fruit trees, the Malay or mountain apple (Syzygium malaccense) and the Polynesian vi-apple or hog plum (Spondias dulcis).

Also almost certainly aboriginal introductions to most areas were the betelnut palm (Areca catechu), the seed of which is an important alkaloid social masticant in Papua New Guinea, Solomon Islands, high-island Micronesia (the Marianas, Palau, Yap, Truk, Pohnpei and Kosrae), and among the south Indians in Fiji); betel pepper (Piper betle), the climbing shrub, the leaves and fruit of which are chewed with betelnut and lime (calcium carbonate); kava (Piper methysticum), the roots and lower stems of which yield the important alkaloid and social beverage of Vanuatu, Polynesia and Pohnpei; the important fibre and handicraft plants, paper mulberry (Broussonetia papyrifera), the bast fiber which is used in bark-cloth manufacture, and a wide range of Pandanus species or cultivars the leaves of which are used in ceremonial and ordinary mat making, for baskets, thatching and for a wide range of plaited ware; and the candlenut (Aleurites moluccana) and the perfume tree (Cananga odorata), so highly valued for scenting coconut oil. The beach almond (Terminalia catappa) and the Indian mulberry (Morinda citrifolia), although native to most groups, are probably both aboriginal introductions into some portions of their range because of their widespread utility. It is also possible that the edible fig species, Ficus aspera, Ficus copiosa, F. damaropsis, F. tinctoria, and F. wassa were introduced deliberately. Other possible aboriginal introductions, into at least some island groups, include Bischofia javanica, so important as a source of red-brown dye for tapa cloth in Polynesia and as a medicinal, soil enhancer and multipurpose tree elsewhere; and Erythrina variegata var. orientalis, a common living fence and boundary marker plant of medicinal and spiritual value. The important ornamental, hedge plants, and multipurpose plants Acalypha amentacea var. wilkesiana, Alpinia spp., Coleus scutelleroides, Hibiscus rosa-sinensis, Pseuderanthemum spp., and a number of hedge panaxes (Polyscias spp.); and the formerly more important "traditional" bamboo Schizostachyum glaucifolium), which has been surpassed in importance by the more recently introduced common bamboo, Bambusa vulgaris, were also probably aboriginal introductions (Thaman 1990b).

Recent Introductions

The 148 "recent" post-European contact introductions include important long-established food trees such as the papaya (Carica papaya); three important banana clones (Musa cultivars), the "Cavendish", "Dwarf Cavendish" and the lady's finger banana or "Pisang Raja"; a range of Citrus species, most important of which are the sweet orange (Citrus sinensis), mandarin orange or tangerine (C. reticulata), lemon (C. limon), sour or Seville orange (C. aurantium) and lime (C. aurantiifolia); the guava (Psidium guajava); soursop (Annona muricata) and sweetsop or sugar apple (A. squamosa); the ubiquitous perennial chili pepper or tabasco (Capsicum frutescens); avocado (Persea americana); and the mango and kaffir lime or rough lemon (C. hystrix), although possibly aboriginal introductions to some areas, are probably recent introductions to most areas. Recent introductions of localized importance are the jakfruit (Artocarpus heterophyllus), pigeon pea (Cajanus cajan), eggplant (Solanum melongena), tamarind (Tamarindus indica), horseradish or drumstick tree (Moringa oleifera), and the Indian bay or curry leaf (Murraya koenigii), all of which are of great importance to the Indian community of Fiji.

Of greater commercial importance, for both plantation or estate and smallholder production, are tea (Camellia sinensis), the coffee species (Coffee arabica C. Canephora, and C.

liberica), oil palm Elaeis guineensis), Para rubber (Havea brasiliensis), and cocoa or cacao (Theobroma cacao), which provide major sources of foreign exchange in a number of the larger countries of the western Pacific.

Introduced exotic timber species of considerable importance include Cordia alliodora, Eucalyptus deglupta and E. saligna, the Caribbean pine (Pinus caribaea), and West Indian mahogany (Swietenia macrophylla), all of which are grown in large-scale continuous stands on a strictly silvicultural basis, as well as in smaller community-level woodlots or as intercrops or along fencelines in agricultural systems. Minor introduced timber species of only minor or localized agroforestry importance include Anthocephalus cadamba, Cedrella odorata, Eucalyptus spp., Gmelina arborea, Grevillea robusta, Maesopsis eminii, Tectona grandis, and Toona australis. Species which are native to areas of the western Pacific, but which have been planted to various degrees on other islands include Agathis spp., Albizia spp. (including Albizia falcataria which, although a recent introduction in most areas, is native to New Guinea), hoop pine (Araucaria cunninghamii), Endospermum spp., and Pterocarpus indicus. In Fiji the Mexican cypress (Cypressus lusitanica), Caribbean pine (Pinus caribaea) and Juniperus sp. are planted on a small scale to supply Christmas trees for the Suva market.

Other recent introductions include the common bamboo (Bambusa vulgaris), sea-island cotton (Gossypium barbadense), kapok (Ceiba pentandra), the neem tree (Azararicta indica), of particular spiritual and medicinal importance to the Fiji Indian community, and the two essential oil trees from the West Indies, allspice (Pimenta doica) and bay rum tree (Pimenta racemosa).

Fast-growing trees of considerable importance in timber and firewood scarce areas, include Acacia, Calliandra and Cassia spp. fiddlewood (Citharexylum spinosum), madre de cacao (Gliricidia sepium), Piper aduncum, Madras thorn (Pithecellobium dulce), Sesbania grandiflora, Acacia spp., Calliandra spp., and, of particular importance, leucaena (Leucaena leucocephala).

Particularly common recent exotic introductions, especially in urban areas, but also around settlements and homes in rural areas are a wide variety of introduced ornamental trees and shrubs including the orchid tree (Bauhinia spp.), bougainvillea (Bougainvillea spp.), a wide range of flowering cassias (Cassia spp.), poincianna, flamboyant or flame tree (Delonix regia), the weeping fig or banyan (F. benjamina), lantana (Lantana camara), Persian lilac or China berry (Melia azedarach), the ubiquitous plumerias or frangipanis (Plumeria rubra and P. obtusa), monkeypod or rain tree (Samanea saman), African tulip tree (Spathodea campanulata), yellow cider (Tecoma stans), many of which are major sources of fuelwood in urban areas and rural houseyard gardens.

As suggested before, many of these introduced species are long-established, in some cases naturalized, having shown their cultural and environmental suitability to the extent that they are often considered indigenous or traditional" to some observers.

Habitat and Range

Of the 419 tree or tree-like species, all are found present in agroforestry systems on either high islands or the larger limestone islands of the Pacific Ocean. There are no species of widespread or major local importance which seem to be confined only to the atoll environment.

Only 83 species (19.8%) seem to be ecologically adapted to, or considered culturally important, or commonly found on Pacific atolls, thus reflecting both the poverty of the indigenous and exotic floras as well as the critical importance of all agroforestry species which do successfully grow in the harsh atoll environment. Of these 83 species, 30 are ubiquitous Pacific strand or mangrove species, 26 introduced ornamentals, with the balance consisting of aboriginally introduced plants, recently introduced food plants, a wide range of recently introduced ornamentals, and a small number of recently introduced timber, fuelwood or other useful plants.

The ubiquitous strand and mangrove species, many of which are deliberately planted and/or protected within active agroforestry and agricultural systems and home gardens because of their considerable ecological and cultural importance, include Barringtonia asiatica, Bruguiera gymnorhiza, Calophyllum inophyllum, Cerbera manghas, Clerodendrum inerme, Colubrina asiatica, Cordia subcordata, Ficus tinctoria, Guettarda speciosa, Hernandia nymphaeaefolia, Hibiscus tiliaceus, Lumnitzera littorea, Morinda citrifolia, Neisosperma oppositifolia, Pandanus tectorius, Pemphis acidula, Pipturus argenteus, Pisonia Rhizophora spp., Scaevola sericea, Sida fallax, Sonneratia alba, Terminalia catappa and T. littoralis, Thespesia populnea, Tournefortia argentea, and Vitex trifolia.

Species of considerable potential for fuelwood which seem to do well in the atoll environment include the exotic, Casuarina equisetifolia, Giricidia sepium, and Leucaena leucocephalla, and the apparently indigenous Macaranga carolinensis.

Husbandry Status

As stressed before, the husbandry of agroforestry species ranges from highly intensive cultivation of domesticated species to indigenous wild species which are protected as integral components of agroforestry systems, but rarely, if ever, planted. In between these extremes falls a range of husbandry strategies including the selective planting, protection, and, in some cases, domestication of indigenous species in active agricultural areas and home gardens and the protection and/or utilization of weedy exotic species that have escaped from cultivation. Of the 419 species or groups of species, some 113 are found almost exclusively in a wild state, 127 cultivated and some 179 (180*) are found in both cultivated and wild states (Table 2).

Table 2. Husbandry status of 419 widespread or locally important tree or tree-like species (the total of 420* reflects the inclusion of two distinct varieties of Erythrina variegata, one of indigenous or aboriginal status, which is found in both wild and cultivated (179*), and the other a cultigen of recent origin).

Table 2

Husbandry Status

Husbandry Status	Number
Wild/uncultivated	113
Cultivated	127
Wild and Cultivated	180*
Total	420*

Wild or Uncultivated Species

The 113 wild or uncultivated species are comprised exclusively of the indigenous coastal strand, mangrove and inland forest species commonly protected in forest stands within the context of Pacific island agroforestry systems. Also included in this category are pioneering species such as Alphitonia spp., Antidesma spp., Claoxylon spp., Commersonia bartramia, Glochidion spp., Kleinhovia hospita, Macaranga spp., Melochia spp., and Trema spp., which although not generally protected when clearing new garden plots, are encouraged through selective weeding and become dominant components of the young fallow forest.

Cultivated Species

The strictly cultivated species, on the other hand, are comprised almost entirely of the exotic cultigens described above. These include major and minor fruit or food species; a wide range of ornamentals; exotic timber or fuelwood species; major and minor export crops; and a number of handicraft, medicinal, spiritual or other multipurpose species.

Wild and Cultivated Species

Species which are both cultivated and found in a wild state include a wide range of indigenous species which are also deliberately cultivated, as well as cultigens, mostly exotic, which have escaped or become naturalized, but which are seen as having significant cultural or ecological value.

The cultivated indigenous species include both those species which are indigenous throughout most of their range, but which are also cultivated, as well as selected species, which although only indigenous to part of their current ranges, have been deliberately introduced to other islands. Among the most commonly cultivated indigenous species are the coastal species Barringtonia asiatica, Calophyllum inophyllum, Casuarina equisetifolia, Cerbera manghas, Cordia subcordata, Erythrina variegata var. orientalis, Fagraea berteriana, Ficus tinctoria, Guettarda speciosa, Hernandia nymphaeaefolia, and H. moerenhoutiana, Hibiscus tiliaceus, Inocarpus fagifer, Intsia bijuga, Morinda citrifolia, Neisosperma oppositifolia, Pandanus tectorius, Parinari glaberrima, Pisonia grandis, Premna serratifolia, Scaevola sericea, Terminalia catappa, Thespesia populnea, and Vitex spp., all of which are commonly cultivated or sown in agricultural areas and houseyard gardens because of their multipurpose utility. Some such as Calophyllum inophyllum, Casuarina eqisetifolia, Clerodenrum inerme, Cordia subcordata, Hibiscus tiliaceus, Inocarpus fagifer, Morinda citrifolia, Pandanus tectorius, Premna serratifolia and Thespesia populnea, have particular spiritual importance and are planted in sacred groves, whereas others are planted as living fences, boundary markers or shade trees.

Other more variable or less widely cultivated species, which seem to be indigenous to some islands, include Aglaia spp., Antiaris spp., Barringtonia spp., Bischofia javanica, Casuarina spp., Cycas circinalis, Flacourtia rukum, Decaspermum fruticosum, Dillenia biflora, Diospyros spp., Dodonea viscosa, Euodia spp., Ficus spp., Garcinia spp., Gardenia spp., Garuga floribunda, Melaleuca leucadendra, Micromelum minutum, Parinari spp., Pterocarpus indicus, Santalum spp., Securinega flexuosa, Sterculia spp., Syzygium spp., and the palms Prichardia pacifica, and Veitchia spp. Many of these may have been aboriginal introductions to some parts of their range. Of particular interest, as mentioned above, are a range of cultivated ornamentals, considered to be native to some Pacific islands, but now widely cultivated throughout the tropics and subtropics. These include Acalypha amentacea vars., Alpinia spp., Caryota spp., Codiaeum variegatum, Coleus scuttelarioides, Cyathea spp., Gardenia taitensis, Graptophyllum pictum, Breynia disticha, Ixora spp., Phaleria disperma, a number of panaxes (Polyscias spp.), and Pseuderanthemum spp.

Species indigenous to some of the larger islands of Melanesia which have been deliberately planted or experimented with as timber species for reforestation programmes include members of the genera Acacia, Agathis, Albizia, Araucaria, Endospermum, and Terminalia and Pterocarpus indicus and Securinega flexuosa.

Species which seem to have been either aboriginal introductions and/or indigenous (depending on the locality), that are both cultivated and either commonly naturalized or indigenous include the important food species Artocarpus altilis and A. mariannensis, Cocos nucifera, Saccharum officinarum and S. edule, Metroxylon spp., as well as a range of supplementary food species including Adenanthera pavonina, Barringtonia edulis, Burkella obovata, Canarium spp., Castanospermum australe, Corynocarpus sililis, Dracontomelon vitiensis, edible figs (Ficus aspera, F. copiosa, F. dammaropsis, F. tinctoria, and F. wassa), Finchia cloroxantha, Gnetum gnemon, Musa tryglodytarum, Pangium edule, Pometia pinnata, Syzygium malaccense, other cultigens found wild are candlenut (Aleurites moluccana),betelnut (Areca catechu) and betel pepper (Piper betle), the perfume tree or ylangylang (Cananga odorata) cordyline (Cordyline fruticosa). Schizostachyum glaucifolium, Sida fallax and Solanum uporo.

Most of the above species are commonly found in mature fallow forests where they either are deliberately planted remnants of former cultivation or naturalized escapes or volunteers that have either been protected by agriculturalists or, in some cases, may have been components of the indigenous flora.

Recent Post-European-Contact introductions that have become most widely naturalized, commonly as escapes from cultivation, include the perennial chili pepper (Capsicum frutescens), papaya (Carica papaya), lantana (Lantana camara var. aculeata), leucaena (Leucaena leucocephala), and guava (Psidium guava). Leucaena is a strategically important fuelwood resource in many areas of the Pacific, whereas guava, most of which is collected from wild sources, is also an excellent fuelwood, as well as being an important commercial "crop" for the fruit processing industries of Fiji and Hawaii, where it is processed into juice and puree for export and local sale. Other commonly naturalized species, often as escapes from cultivation, include locally important fuelwood species such as Acacia farnesiana mango (Mangifera indica), fiddlewood (Citharexylum spinosum), Elaeocarpus grandis, Madras thorn (Pithecellobium dulce), raintree or monkeypod (Samanea saman), sesban (Sesbania grandiflora).

Relative Importance

In terms of the relative importance in terms of abundance and/or ecological and cultural utility of the 419 species, Table 3 lists 56 species or groups of closely related species of major agroforestry importance and cultural utility.

Table 3. Tree or tree-like species or groups of closely related species major agroforestry importance in many island groups in terms of abundance and/or ecological importance and cultural utility; those designated by asterisks *, are species of widespread (two asterisks) are localized and (one asterisk*) importance or potential as fuelwood.**

Table 3

Tree or Tree Like Species

Aleurites moluccana	Hibiscus tiliaceus**
Annona muricata	Inocarpus fagifer*
Areca catechu	Leucaena leucocephala**
Artocarpus altilis*	Macaranga spp.**
Bambusa vulgaris**	Mangifera indica*
Bischofia javanica**	Metroxylon spp.
Broussonetia papyrifera	Morinda citrifolia*
Bruguiera gymnorhiza**	Musa AAA 'Robusta'
Calophyllum inophyllum*	Musa AAB 'Pisang Raja'
Cananga odorata*	Musa AAB 'Maia Maoli'
Capsicum frutescens	Musa AAB 'Bluggoe'
Carica papaya	Pandanus tectorius**
Casuarina equisetifolia**	Pandanus spp./cultivars
Ceiba pentandra	Piper methysticum
Citrus hystrix*	Pipturus argenteus
Citrus reticulata*	Plumeria rubra
Citrus sinensis*	Polyscias guilfoylei*
Cocos nucifera**	Pometia pinnata**
Cordia subcordata	Premna serratifolia*
Cordyline fruticosa	Psidium guajava
Delonix regia*	Rhizophora spp.**
Erythrina variegata	Saccharum officinarum*
Fagraea berteriana	Spondias dulcis
Ficus prolixa*	Syzygium malaccensis
Glochidion ramiflorum*	Terminalia catappa*
Guettarda speciosa*	Theobroma cacao
Hibiscus manihot	Thespesia populnea*
Hibiscus rosa-sinensis*	

Also of major agroforestry importance, although not quite as widespread or as abundant in indigenous agroforestry systems, are another 127 species or groups of closely related species listed in Table 19.4. These include:

(a) important food species;

(b) multipurpose aboriginal introductions;

(c) indigenous species which are protected in tree groves and fallow areas and/or planted in agricultural areas;

(d) recently introduced timber, fuelwood and multipurpose species

(e) important export crops; and

(f) a wide range of commonly cultivated ornamentals.

Table 4. Tree or tree-like species or groups of closely related species of major agroforestry importance in certain localities and/or widespread supplementary ecological or cultural importance.

Table 4

Tree or Tree Like Species or Groups of Related Species

Acalypha amentacea vars.	Diospyros samoensis*	Myristica spp.*
Adenanthera pavonina	Diospyros spp.*	Neisosperma
Aglaia saltatorum	Dracontomelon vitiensis	oppositifolia
Aglaia spp.	Dysoxylum forsteri*	Nerium oleander
Albizia lebbek	Dysoxylum spp.*	Pandanus conoideus
Albizia falcataria	Elaeocarpus spp.*	Pandanus dubius*
Alphitonia spp	Elaeis guineensis	Pandanus julianettii*
Alyxia spp.	Endospermum spp.*	Pangium edule
Annona squamosa	Eucalyptus deglupta*	Parinari glaberrima'
Antiaris toxicaria	Eucalyptus spp.*	Pemphis acidula**
Araucaria cunninghamii	Euodia hortensis	Persea americana
Araucaria heterophylla	Euodia spp.	Phaleria spp.*
Artocarpus heterophyllus	Ficus benjamina*	Pinus caribaea*
Artocarpus mariannensis	Ficus copiosa	Pisonia grandis
Barringtonia asiatica	Ficus dammaropsis	Planchonella. spp.*
Barringtonia edulis	Ficus obliqua*	Plumeria obtusa
Bauhinia monandra*	Ficus tinctoria*	Polyscias fruticosa*
Bougainvillea spp.	Ficus wassa	Polyscias scutellaria
Burkella obovata	Ficus spp.*	Prichardia pacifica
Cajanus cajan*	Garcinia sessilis	Pterocarpus indicus*
Canarium indicum*	Garcinia spp.	Rhus taitensis*
Canarium spp.*	Gardenia taitensis	Saccharum edule
Cassia alata	Gardenia jasminoides	Santalum spp.
Cassia fistula*	Garuga floribunda*	Scaevola sericea*
Cassia grandis*	Gliricidia sepium*	S c h i z o s t a c h y u m
Casuarina oligodon*	Gnetum gnemon	glaucifolium*
Cerbera manghas	Grewia crenata*	Securinega flexuosa*
Citrus aurantiifolia	Heliconia indica	Sida fallax
Citrus aurantium	Hernandia nymphaeaefolia	Solanum melongena
Citrus grandis*	Homalanthus spp.	Spathodea campanulata
Citrus limon	Intsia bijuga	Sterculia spp.
Codiaeum variegatum	Ixora spp.	Swietenia macrophylla*
Coffee arabica	Jatropha curcus	Syzygium cumini*
Coffee canephora	Kleinhovia hospita*	Syzypium richii
Coleus scutuillariodes	Lantana camara*	Syzygium spp.*
Commersonia bartramia*	Lumnitzera littorea*	Tamarindus indica*
Cordia alliodora*	Melaleuca leucadendra*	Tarenna sambucina
Cryptocarya spp.	Melastoma malabathricum	Terminalia spp.*
Cyathea spp.*	Metrosideros collina	Tournefortia argentea*
Cycas circinalis	Micromelum minutium	Trema spp.*
Decaspermum fruticosum*	Moringa oleifera	Vitex spp.
Dendrocnide spp.	Musa tryglodytarum	
Derris spp.	Musa cultivars	

Species of Particular Importance for Agroforestry-Based Fuelwood Development

It is estimated that no less than 80% of these species are used as fuelwood or biomass in the Pacific islands. However, ethnobotanical data on use of widespread Pacific species for fuelwood is scarce, as most researchers seem to have failed to include fuelwood use as a category along with food, medicine, perfumes, fiber, dyes, etc. or have lumped it together with timber. Based on a few systematic studies by the author and those sources that are available (Thaman and Ba 1979, Siwatibau 1981, Thaman 1985, 1988a, 1989b, 1990c, King 1985), those species that seem to be of particularly widespread importance as sources of high quality or widely used fuelwood, which currently constitute major fuelwood resources in some areas of the Pacific include: Albizia lebbek, Alphitonia spp., Bambusa vulgaria, Bruguiera gymnorhiza, Casuarina equisetifolia, Cocos nucifera, Eucalyptus spp., Hibiscus tiliaceus, Leucaena leucocephala, Macaranga spp., Pandanus tectorius, Pemphis acidula, Pometia pinnata, Psidium guajava, Rhizophora spp. and Samanea saman.

Those of localized or potentially great fuelwood importance because of their quality, widespread availability, multiple-utility, or ease and speed of production include: Acacia spp., Adadirachta indica, Adenanthera pavonina, Albizia falcataria, Annona muricata, Annona spp., Araucaria spp., Artocarpus altilis, Artocarpus heterophyllus, Barringtonia spp., Bauhinia monandra, Cajanus cajan, Calliandra spp., Calophyllum inophyllum, Cananga odorata, Canarium spp., Cassia spp. Casuarina oligodon, Citrus spp., Commersonia bartramia, Cordia alliodora, Cyathea spp., Decaspermum fruticosum, Delonix regia, Dillenis biflora, Diospyros spp., Dysoxylum spp., Elaeocarpus spp., Elattostachys falcata, Endospermum spp., Eucalyptus spp., Ficus spp., Garuga floribunda, Gliricidia sepium, Glochidion spp., Gmelina arborea, Grewia crenata, Guettarda speciosa, Hibiscus rosa-sinensis, Inga edulis, Inocarpus fagifer, Kleinhovia hospita, Lantana camara, Lumnitzera littorea, Mangifera indica, Melochia spp., Melaleuca leucadendra, Melia azadirachta, Morinda citrifolia, Muntingia calabura, Myristica spp., Pandanus spp., Parinari spp., Phaleria spp., Pinus caribaea, Piper aduncum, Pithecellobium dulce, Pittosporum spp., Planchonella spp., Polyscias spp., Pongamia pinnata, Premna spp., Psidium cattleianum, Pterocarpus indicus, Rhus taitensis, Saccharum officinarum, Scaevola sericea, Schizostachym glaucifolium, Securinega fllexuosa, Sesbania grandiflora, Swietenia macrophylla, Syzygium cumini, Syzygium spp., Terminalia catappa, Terminalia spp., Tamarindus indica, Tournefortia argentea, Trema spp., Xylocarpus spp. Xylosma spp. Some of these, although not currently used widely in the Pacific, are major sources of fuelwood and charcoal in Asia and other parts of the developing world (N.A.S. 1980, Little n.d.).

Those species present in some areas of the Pacific, not listed in Tables 3 or 4, but which could be of significant value in agroforestry-based fuelwood production strategies include: Cassia siamea, Clerodendrum inerme Cynometra spp., Cyrtandra spp., Ervatamia orintalis, Indigofera suffruticosa, Parasponia spp., Solanum verbascifolium, Sonneratia alba and Suriana maritima. Species of good fuelwood value, but because of their scarcity and wide cultural utility as food plants, sources of high quality carving wood for handicrafts, should be reserved for those purposes, include: Cordia subcordata, Intsia bijuga, Pongamia pinnata, and Thespesia populnea.

Taken together, as a polycultural and multiple-utility resource, these fuelwood species constitute a formidable basis for sustainable agroforestry based fuelwood development.

Multipurpose indigenous species of particular localized importance are Casuarina oligodon, Pterocarpus indicus and Sicurinega flexuosa. C. oligodon is widely planted in active and abandoned garden areas as an improved fallow in highly populated areas of highland Papua New Guinea and Irian Jaya as part of an agricultural intensification strategy. The timber is used for fuelwood, fence posts, general construction and other purposes, and its known nitrogen-fixing ability helps in restoring soil fertility. P. indicus is planted as living fencing and has been planted experimentally as a timber species in Vanuatu, and S. flexuosa (also referred to as S. samoana in the literature) is widely planted in rural garden areas and houseyard gardens in Samoa for its timber which is favored for house poles and used for general construction and fuelwood. It is also planted to a lesser extent in Vanuatu and other parts of Melanesia and has been experimented with in Vanuatu and introduced into the Cook Islands for use in institutionalized silvicultural programs.

The bamboo species, Schizostachyum glaucifolium (most probably an aboriginal introduction), which is a traditional component of agroforestry systems from Melanesia to Hawaii is sometimes planted and widely protected in tree groves and fallow areas throughout the Pacific which is valued for general construction, handicrafts and a range of other cultural uses. In many localities, however, it has been surpassed in importance by the larger recently-introduced common bamboo (Bambusa vulgaris). Both are used as fuel.

A fuelwood species of increasing agroforestry importance, particularly in Vanuatu and Fiji is glyricidia or mother of cocoa (Glricidia sepium), which is planted as windbreaks and living fencing or for shade and green manure in cocoa and sugar plantations and as living fencing around dairy and beef cattle pastures. Also of increasing importance is the jambolan (Syzygium cumini) which has been widely planted as windbreaks and as a fuelwood species in the Cook Islands and Tahiti and to a lesser extent in Fiji, where it is valued as a minor fruit or snackfood species.

The Usefulness of Trees

Central to an understanding of the importance of traditional agroforestry is the utilitarian diversity of the trees of traditional agroforestry systems. Whereas modern developers think of trees in terms of their economic value and, sometimes, in terms of their ecological, recreational, nutritional or biomass and energy values, it is clear that Pacific island people considered forests and trees to be far more useful. Whether in native forests, pine or mahogany plantings, coconut, cocoa, coffee, banana, orange, or papaya plantations, trees are usually seen by developers as sources of cash income (Thaman and Clarke, 1990a). Table 5 shows some of the diverse functions and traditional uses of trees in the Pacific.

Table 5

Ecological and cultural functions and uses of trees in the Pacific islands.

ECOLOGICAL		
Shade	Soil improvement	Animal/plant Habitats
Erosion Control	Frost Protection	Flood/runoff Control
Wind Protection	Wild Animal Food	Weed/disease Control
CULTURAL/ECONOMIC		
Fuelwood/biomass	Broom	Prop or Nurse Plants
Timber(subsistence)	Parcelisation/wrapping	Staple foods
Timber)commercial)	Abrasive	Supplementary Foods
Boatbuilding(canoes)	Illumination/torches	Wild/snack/emergency
Sails	insulation	Foods
Tools	Decoration	Spices/sauces
Weapons Hunting	Body Ornamentation	Teas/coffee
Containers	Cordage/lashing	Non-alcoholic Beverages
Woodcarving	Glues/adhesives	Alcoholic Beverages
Handicrafts	Caulking	Stimulants
Fishing Equipment	Fibre/fabric	Narcotics
Floats	Dyes	Masticants
Toys	Plaited Ware	Meat Tenderizer
Switch for Children/	Hats	Preservatives
Discipline	Mats	Medicines
Brush/paint Brush	Baskets	Aphrodisiacs
Musical Instruments	Commercial/export	Fertility Control
Cages/roosts	Products	Abortifacients
Tannin	Ritual Exchange	Scents/perfumes
Rubber	Poisons	Recreation
Oils	insect Repellents	Magico-religious
Toothbrush	Deodorants	Totems
Toilet Paper	Embalming Corpses	Subjects of Mythology
Fire Making	Lovemaking Sites	Secret Meeting Sites

Source: Adapted from Thaman and Clarke, 1987.

In terms of the ecological importance of trees, shade is important to humans, plants, and animals, especially in open grasslands, in highly reflective low-lying coral island and lagoonal environments, and in villages and urban areas. Damage from wind, salt spray, erosion, and flood are increased when forests are removed. Cases of deforestation leading to accelerated erosion are common in all island groups. Mangrove forests stabilize tidal-zone soil and reduce the impact of storm surge and salt spray. Natural soil improvement is another benefit provided by trees, especially given the high cost of imported fertilizers. The value of forests and trees as a habitats for plants and animals cannot be overstated. Bird extinctions have been common on Pacific islands, and seem to be primarily the result of habitat destruction through deforestation.

The importance of fuelwood and biomass is taken as a given, and there is no need to stress the importance of timber, except to note that commercial timber operations supply local construction needs as well as generating foreign exchange. Trees are also used for house construction, fencing, boatbuilding, toolmaking, weaponry, making containers, fishing gear, and many other purposes. The coconut is a storehouse of materials for house building, mat making, containers, fish traps (roots), and an endless array of handicrafts; the breadfruit for canoe making; bamboo for fishing poles, housing, and rafts; and many species for handicrafts. Many of these species such as vesi (Intsia bijuga), nawanawa (Cordia subcordata), and mulomulo (Thespesia populnea) are favored for woodcarving, but are now in short supply in Fiji because of over exploitation.

Foods from trees are of immense value, whether as staples, supplementary foods, occasional snacks, or famine foods. The nutritional importance of dominant staple tree crops, such as coconut, breadfruit, and bananas and plantains, and the wide range of fruit and nut trees is critical to the nutritional wellbeing of Fiji's people. Spices and sauces from tree products can also be of great nutritional importance. Coconut cream or milk is used very widely in cooking, and local variants of the Rotuman taroro or Fijian miti enhance local cuisines, and Indian cooking utilizes tamarinds for chutney, the "curry leaf" (tejpatti), a wide range of pickled fruits (achar), and many other tree products in their cooking. Trees are also important sources of food and fodder for domesticated animals.

Wild food and other valuable products are lost to subsistence communities when the plants and animals that supplied them disappear along with the forest and trees that served as their habitats. Mangroves contribute to the nutritional requirements of a high proportion of marine food species. Research in Fiji has shown that over 60% of commercially important fish species are associated with mangroves at some stage in their life cycle and that mangrove removal can lead to yield declines in offshore fisheries of 50 to 80 % (Baines 1979, Watling 1985).

Medicinal plants are an important economic and cultural resource, given the extremely high, and rapidly increasing costs, not to mention unavailability, misuse, and doubtful effectiveness of some imported medicines. In Suva, 40% (73) of 183 medicinal plants used by Fijians are found in home gardens. The totals would undoubtedly be much higher if data on Indian medicinal plants were also available (Thaman 1987, 1988b).

Other uses of tree products include wrapping material, perfumes, and garlands. In Tonga, there are over 50 species of sacred or fragrant plants, known as 'akau kakala, which are of great spiritual and economic importance to Tongan society. The Fijian equivalent is saluaki, and neem, mango, coconut, betelnut, and banyans have spiritual importance in the Hindu religion (Thaman 1988b).

The diverse cultural importance of trees is further stressed in a study of the ethnobotany of Pacific island coastal plants which stresses in detail the degree of utilitarian diversity and cultural importance of some 88 shrub and tree species which are ubiquitous or locally important in mangrove and coastal strand vegetation, 68 of which are included in the 419 species described above (Thaman 1989b, 1990bc). The study shows that there are some 69 different purpose/use categories for coastal plants, with the total frequency of usage for the 88 shrub and tree species being 808, an average of 9.2 purpose/use categories per plant, ranging from two reported uses per species to as many as 121 for the coconut, if distinct uses within categories (e.g., tools with distinct functions) are counted (Tables 6 and 7). Next in order of importance, all with 20 or more reported uses, are Hibiscus tiliaceus, Pandanus tectorius, Calophyllum inophyllum, Cordia subcordata, Guettarda speciosa, Scaevola scricea, Pemphis acidula, Thespesia populnea, Rhizophora spp., Casuarina equisetifolia, Premna serratifolia, Morinda citrifolia, Ficus prolixa and Tournefortia argentea, with a total of 39 species having at least 7 uses each (7). There is some usage overlap between categories, such as supplementary and emergency foods and medicinal plants, magical, ceremonial and body ornamentation plants, or plants used for handicrafts, woodcarving, cordage, and clothing. Conversely, the categories could be further broken down to yield an even greater list of uses (e.g., 121 for coconut). Moreover, the list does not include the more strictly ecological functions of coastal plants, such as shade, protection from wind, sand and salt spray, erosion and flood control, coastal reclamation, animal and plant habitats, and soil improvement, all of importance to Pacific societies.

In terms of specific uses, the most widely reported uses are for medicine, general construction, fuelwood, body ornamentation, ceremony and ritual, cultivated or ornamental plants, toolmaking, food, boat or canoe making, dyes or pigments, magic and sorcery, fishing equipment, cordage and fibre, games or toys, perfumes and scenting coconut oil, woodcarving, weapons or traps, food parcelization, subjects of legends, mythology, songs, riddles, and proverbs, fertilizer and mulching, domesticated and wild animal feed, handicrafts, cooking equipment, clothing, fish poisons, items for export of local sale, adhesives or caulking, and musical instruments, all of which were reported for at least eleven species (Table 6). The analysis, however, is based on traditional uses, many of which have lapsed or are only employed in emergency, because modern technology has pre-empted them.

Table 6. Frequency of the usage for specified purposes of 88 Pacific island widespread coastal shrub and tree species.

Table 6

Frequency of Usage

Purpose/use	Shrubs x/26	Trees x/62	Total x/88
Medicinal/health	23	51	74
General Construction	6	54	60
Firewood/fuel	8	43	51
Body Ornamentation	12	26	38
Tools/toolmaking	4	32	36
Boat/canoe Building	3	30	33
Cultivated/ornamental	10	20	30
Ceremony/ritual	6	22	28
Dyes/pigments	3	23	26
Fishing Equipment	7	17	24
Emergency/famine Foods	4	18	22
Games/toys	4	16	20
Woodcarving	1	18	19
Magic/sorcery	5	14	19
Weapons/traps	5	14	19
Legends/mythology	3	15	18
Supplementary Foods	3	14	17
Scenting Oil/perfumery	6	11	17
Fertilizer/mulching	4	11	15
Cooking Equipment	1	12	13
Food Parcelizition	1	11	12
Cordage/fibre	3	9	12
Musical Instruments	1	10	11
Export/local Sale	2	8	10
Animal Feed	2	8	10
Adhesive/caulking	-	9	9
Handicrafts	1	8	9
Clothing	1	8	9
Fire by Friction	1	8	9
Containers	1	7	8
Repellents/fumigants	2	6	8
Fish Poisons	4	4	8
Tannin/preservatives	1	6	7
Wild Animal Foods	2	5	7
Staple Foods	-	5	5
Land Reclamation	-	5	5
Calendars/clocks	-	5	5
Antitoxins	1	4	5
Living Fences/hedges	1	4	5
Soap/shampoo	3	2	5
Illumination	-	4	4
Combs	-	4	4
Animal Cages/roosts	-	4	4
Thatching/roofing	1	3	4
Contraceptives/ Abortifacients	3	1	4
Oils/lubricants	-	3	3
Strainers/filters	-	3	3
Brushes	-	3	3
Fans	-	3	3
Corks	-	3	3
Drinks/beverages	1	1	2
Other Uses*	5	28	33
TOTAL	155	653	808

* Other uses include stimulants/teas, aphrodisiacs, hair remover, masticants/chewing gum, abrasive, tooth brushes, cigarette wrappers, coconut climbing bandages or harnesses, measuring tapes, fireworks, windbreaks, sand screens, ladders, tethering posts, fish bait, punishment, communication/language, and computation or counting.

Table 7. Coastal shrub and tree species of particular cultural utility based on the number of different uses listed in Table 6 Note: not including a wide range of ecological functions or uses).

Table 7

Coastal Shrub and Tree Species

Latin Name	Uses
Cocos nucifera	121
Hibiscus tiliaceus	56
Pandanus tectorius	48
Calophyllum inophyllum	42
Cordia subcordata	37
Guettarda speciosa	33
Scaevola sericea	30
Pemphis acidula	27
Thespesia populnea	26
Rhizophora spp.	24
Casuarina equisetifolia	22
Premna serratifolia	22
Morinda citrifolia	21
Ficus prolixa	20
Tournefortia argentea	20
Terminalia catappa	19
Erythrina variegata	19
Ficus tinctoria	19
Inocarpus fagifer	18
Pipturus argenteus	18
Lumnitzera littorea	17
Pisonia grandis	17
Bruguiera gymnorhiza	15
Hernandia nymphaeaefolia	15
Nypa fruticans	14
Barringtonia asiatica	13
Intsia bijuga	13
Cycas circinalis	13
Gardenia taitensis	11
Sida fallax	11
Santalum spp.	10
Mammea odorata	10
Vitex spp.	10
Dodonea viscosa	10
Cerbera manghas	10
Clerodendrum inerme	9
Ficus obliqua	8
Neisosperma oppositifolia	8
Metroxylon spp.	7

These few examples of the usefulness of trees highlight values of trees and forests that are rarely acknowledged in planning or project documents, but which would be extremely costly, difficult, or impossible to replace with imported substitutes. The elimination of such utilitarian and cultural diversity can only serve to lock Pacific societies more tightly into the vicious circle of economic and cultural dependency.

Hybrid Agroforestry Development as a Strategy to Address the Problem of Increase Fuelwood Scarchity

Fortunately, the fuelwood situation in the Pacific is not yet beyond hope as it appears to be in some areas of the world because most traditional agroforestry and fuelwood production strategies of the Pacific Islands and the knowledge of the utility of trees have been preserved. Nonetheless, increasing agrodeforestation and the gradual disappearance of time-tested agroforestry systems in the face of monoculture, expansion of commercial livestock production, population growth, demands for fuel, continued urbanization, and the commercial imperative" (Tudge, 1977) are the dominant trends that will only be reversed by deliberate planning and action.

It is argued here that the promotion of a hybrid future Pacific Island agroforestry and the protection of trees in local agroecosystems is among the most appropriate actions to take to promote sustainable fuelwood and biomass production to satisfy the increasing needs of the populations of the isolated, fragmented, and resource-poor islands of the Pacific. Conversely, agrodeforestation", deforestation, and the neglect of trees, in the name of modernization and development, will make sustainability of fuelwood production problematic or impossible.

Such future agroforestry-based fuelwood system development should, however, not be imposed from outside the Pacific region and based on exotic species. Rather, it should be a hybrid agroforestry based firmly on the dynamic existing polycultural and utilitarian systems of the Pacific islands, strengthened with appropriate introduced trees and technologies. Such a model would seem to have the greatest potential for meeting fuelwood needs in the face of the changing ecological, demographic, economic, and social challenges in the islands. Moreover, it is suggested that the systematic promotion of polycultural agroforestry at national and community levels could be one of the more cost-effective strategies for addressing many of the other commonly stated development goals of Pacific countries.

Such hybrid agroforestry development and sustainable fuelwood development will be problematic, however, if planners and policy makers promote only modern or imported agribusiness and agroforestry systems and strategies without a sound understanding of traditional systems. In this vein, this study has attempted, as one of its main objectives, to provide a better understanding of the importance and developmental potential of present and past Pacific island agroforestry systems as bases for sustainable fuelwood development and economic and cultural viability in the small island states of the Pacific Ocean.

Recommendations

Although there are countless recommendations that could be made with respect to the systematic promotion of hybrid agroforestry-based fuelwood development and the reversal of "agrodeforestation" and deforestation in the Pacific islands, the following are some general recommendations that could serve as an initial blueprint for appropriate action:

(a) That multimedia programs be developed, in the vernacular, to stress the nature and long term economic, social, and ecological importance of existing agroforestry systems, the need for sustainable fuelwood development and the problems associated with deforestation and agrodeforestation;

(b) That units be written for use in school science or social science/geography curricula, at appropriate levels, on the nature and importance of traditional Pacific island

agroforestry and fuelwood systems and the effect agrodeforestation has on them (such units should be examinable and include field activities for both rural and urban areas);

(c) That governments require that all agricultural and forestry students and employees of relevant government sections and AID agencies or volunteer organizations working in the areas of agriculture, forestry, or agroforestry undergo an intensive field component of training or orientation, during which they would be required to conduct in-depth surveys of tree species existing in active agricultural areas, their cultural ecology and husbandry, and their cultural and economic importance.

(d) That intersectoral working groups or committees be established in all countries to compile published lists (with both vernacular and Latin names) of long-established traditional and potentially-important introduced tree species (including fuelwood species) that should be protected and/or promoted in institutional agroforestry development.

(e) That in-depth research be funded and conducted to study existing agroforestry and fuelwood systems, their component plants, cultural ecology and husbandry, and their economic, particularly their subsistence economic, importance, in the context of national and agroforestry development.

(f) That all landholders/owners be encouraged to preserve representative areas of primary and secondary forest and other natural vegetation associations as ecologically-important and culturally-utilitarian components of their agroforestry systems.

(g) That national park and conservation area development include the promotion and establishment of village-level agroforestry reserves.

(h) That the nutritional and economic importance of wild foods and other wildland resources be wide y stressed, and included as a capital item, in development plans and be made a component of environmental impact assessment procedures.

(i) That, where possible, the protection of useful trees and the intercropping and border planting of trees and tree-like plants be required or encouraged in all agricultural, agroforestry, livestock, tourism, and urban-industrial development projects.

(j) That the nutritional importance of trees be documented and stressed in the media, and be made a component of environmental impact assessment procedures.

(k) That the utilitarian diversity and subsistence importance of tree products with regard to their replacement cost by imported substitutes be documented, stressed in the media, and made a component of environmental impact assessment procedures.

(l) That houseyard agroforestry, in urban and rural areas, be systematically promoted as one of the most cost-effective means of achieving sustainable agroforestry-based fuelwood development.

(m) That coconut replanting and rehabilitation schemes be:

(i) continued, but that

(ii) increased spacing between rows and perhaps decrease within row spacing be promoted to a allow for increased intercropping with groundcrops and treecrops,

(iii) that indigenous and introduced utilitarian species be protected and replanted within coconut plantations, and

(iv) that senile coconuts resources be systematically used as part of national fuelwood development strategies.

(n) That agricultural, forestry, health-nutrition, and energy-development programs and projects include the systematic replanting and production of planting material of strategic multipurpose fuelwood species and cultivars.

(o) That the use of fuelwood species as durable living fencing or hedging, boundary markers, windbreaks, and living animal pens be actively promoted.

(p) That the maintenance of fuelwood resources be made a priority and that traditional and recently-introduced species be planted as part of both rural and urban agroforestry systems, in single-species stands or, as may be more appropriate, as part of multi-faceted fuelwood production strategies which might include intercropping, taungya, living fencing, pruning and pollarding, coppice systems, selective weeding, use of deadwood, driftwood and coconut by-products.

(q) That the magico-religious or spiritual importance of sacred groves or individual living trees (and their parts such as flowers) be popularized in an attempt to get landowners to protect representative vegetation associations and tree groves.

(r) That the integration of livestock into agroforestry and cropping systems (rather than dissociation) be made a priority in agricultural development.

(s) That the practice of selective weeding to encourage valuable pioneer fuelwood species to establish themselves in fallow areas and houseyard gardens be promoted.

(t) That deliberate planting, transplanting or protection of indigenous species, often from endangered coastal vegetation associations, into both agricultural areas and houseyard gardens be actively encouraged.

(u) That the establishment and protection of permanent polycultural orchards including multipurpose fuelwood species), particularly around villages and in commercial agricultural and urban areas, be actively encouraged.

(v) That severe pruning, pollarding, and coppicing be encouraged as an alternative to complete removal of trees, when clearing new garden areas for both commercial and subsistence crops or livestock production.

(w) That the use of minimum or restricted tillage and the use of appropriate hand tools, which favor the survival of trees, be encouraged as an alternative to complete tillage or ploughing.

In conclusion, deforestation, forest degradation and agrodeforestation, and the associated plunder of fuelwood and biomass resources, are proceeding at frightening rates in the Pacific islands, with some islands having been completely deforested and/or agrodeforested before the time of European contact. There is, however, great potential for sustainable hybrid agroforestry development, agroforestry-based fuelwood and biomass and the reversal of agrodeforestation in the Pacific islands. By Hybrid agroforestry and fuelwood system "development", I refer to the expansion, intensification, strengthening, and adaptation of existing agroforestry and fuelwood production systems and strategies to changing demographic, social, aspirational, and ecological conditions. Such agroforestry will foster systematic diversification and enrichment of plant resources in contrast to the monocultural models now often favored. It will also require improved understanding of existing agroforestry systems coupled with systematic programs of protection, replanting, duplication, and distribution of appropriate planting materials.

Through such a hybrid (traditional + modern, the traditional being deliberately placed first!) approach, it should be possible to promote a true "Green Revolution", which will encourage, rather than discourage or undermine, diversification, tree planting, on-the-farm and in-the-town fuelwood self-sufficiency, economic and subsistence stability, and cultural preservation. The tools are before us in the form of the trees and technologies of the ever-evolving and dynamic traditional agroforestry and fuelwood systems that have served Pacific societies for millennia. The task before us, as members of an urban-biased, and urban-based managerial elite is to take time to listen, observe and learn from traditional agroforesters and energy planners, women and men alike, about their existing systems before we enthusiastically impose, or try to impose, alien, often monocultural and socially- and ecologically-untested systems. Through such an approach we could promote "agroforestation" and an innovative and sustainable "Green Agroforestry and Sustainable Energy Revolution", or, perhaps more appropriately, "Evolution" in the rapidly modernizing and increasingly deforested, agrodeforested and energy-dependent small-island states of the Pacific Ocean.

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FUELWOOD ISSUES IN PACIFIC ISLAND COUNTRIES - LESSONS FROM WITHIN AND OUTSIDE THE REGION

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Introduction

For the foreseeable future, most Pacific Island Countries (PICS) will continue to rely heavily on fuelwood and related woody biomass fuels for domestic cooking and water heating and for industrial process heat, particularly in crop drying. Foreign exchange and technical limitations prevent large-scale substitution of woody biomass by technically feasible alternatives such as petroleum fuels and electricity.

In PICs there exists a diversity of forest conditions - from primary forest remaining in many areas of the larger islands, to largely cleared farming landscapes such as parts of western Viti Levu in Fiji, and large areas of grassland subjected to shifting subsistence agriculture by recent settlers and repeated burning, as for example around Honiara and Port Moresby. There is also a great diversity of site potentials, from well-watered, fertile sites that support some of the fastest-growing trees in the world to sites where tree growth is almost impossible because soils are too shallow, infertile or saline. Household energy surveys in a number of PICs (e.g. PEDP 1985; PEDP 1986; PEDP 1988) have identified developing fuelwood shortages and rising fuelwood prices around major urban areas.

The points I wish to make in this paper relate to the ways in which supplies of and demand for biomass fuels can reach a stable regional balance. I will mention technical matters that affect tree growth, but I want to emphasize that it is the relationship between people and their land, agriculture and trees, which determines whether a balance can be reached.

Westoby (1989) has recently provided a good overview of world forestry. He draws attention to the changing role of foresters in the emerging areas of social forestry and agroforestry, where the emphasis is on growing trees to meet people's local needs and strengthen their agricultural systems. The methods, costs and benefits are quite different to those of large-scale forestry plantations for industrial wood production.

Can Governments and NGOS Contribute?

Most of the effort to rectify a fuelwood shortage and reach a balance between supply and demand for fuelwood must come from the people living and working in the region where the problem occurs. Effective contributions by governments and NGOS depend on the following:

(a) there must be genuine two-way communication with the people living and working in the area, so that project managers achieve an accurate understanding of the local situation and peoples' perception of it;

(b) landowners must perceive that it is in their interest to increase tree numbers and wood fuel production;

(c) agencies must be capable of providing real assistance to people through demonstration of new agroforestry technologies, provision of new or improved tree species, or the ability to overcome technical problems in tree-growing through research and extension; and

(d) relevant agencies with required expertise agriculture, forestry, and perhaps energy officials if there are technical problems in biomass fuel transport, marketing and use), must coordinate their activities, so that farmers get a coherent, consistent message.

Large-Scale Fuelwood Plantations

The prospects for large-scale fuelwood plantations in PICs were reviewed by Harwood 1985). The conclusions reached in that report remain substantially valid. In most circumstances, large-scale fuelwood plantations appear unlikely to be economically viable. The first-year cost of establishing plantations is now of the order of US$ 1000 per hectare or more in most PICs. This is likely to make the cost of growing wood in plantations at least US$ 20 per tonne at 30% m.c. (wet weight basis), given realistic assumptions about land rental values, tree growth rates and interest rates. The selling price to wood-fired power stations, industry or urban fuelwood markets would be much higher because of the additional costs of harvesting, transport, storage and marketing. Wood currently being sold in urban markets in PICs is being harvested as a free good, without bearing the cost of growing it as a crop. It is therefore difficult for fuelwood grown in commercial plantations to compete in these markets until supplies of "free" wood are exhausted. The additional costs involved in growing wood in fuelwood plantations will also often make it uncompetitive with petroleum alternatives. Suitable land for plantations close to urban centers or industries, where fuelwood markets exist, may be unavailable or too expensive.

Government-owned and managed eucalypt plantations in the Waghi Valley in Papua New Guinea's highlands have supplied local industry with large quantities of wood fuel for process heat for tea drying. In this example, the high cost of transport from the coast to the highlands raises the price of the competing fuel (diesel), and secure land tenure, ideal climate and fertile soil provide favorable growing conditions for fuelwood close to the factories.

Agro-industrial Residues

Coffee husks, and coconut shells and husks, provide an important fuel source for crop drying industries in PICs and should not be neglected in regional energy balance calculations in areas where these crops are processed. The copra industry can be a net exporter of biomass fuel (surplus husk and shell) and the coffee industry can supply most of its process heat requirements, using efficient drying and combustion techniques described by Gilmour (1987). Sawmill residues are also a major source of biomass fuel where available, and make an important contribution to domestic fuel supplies in some towns.

Integrating Trees into Agricultural Production Systems

This is the most effective way to bring supply and demand for biomass fuels into balance. Trees grown in farming systems can provide a steady supply of wood fuel and other forest products, while interfering only marginally, or actually improving, food production. Examples from around the world are being documented in the developing science of agroforestry (see, for example, ICRAF 1990). The economics of farmers planting, growing and harvesting their own trees on their own land are much more favorable than those of government or NGO intervention to establish large scale fuelwood plantations.

Once farmers perceive a need for increasing tree numbers on their land, what are the options?

Protection and Propagation of Valuable Local Trees

This can be the easiest option, requiring the lowest external inputs. A good example comes from Nepal, a country that has received notoriety in the world media for deforestation of the Himalayan foothills. The situation is quite different on closer inspection. In an area studied by Carter and Gilmour 1988), tree cover on hill farms more than doubled from 1964 to 1988. An estimated 13 million new trees established on 55,000 ha of cultivated land over the period, equivalent to 6,500 hectares of new forest plantations. The farmers actively protected already-established trees, and planted locally available seedlings. Most of the additional trees were grown on the sloping walls that separate the flat terraces where food crops are cultivated. These farmers were responding on their own initiative to a need for forest products (animal fodder, building materials and firewood), with no government assistance. If the equivalent area of plantations had been established with government or aid funding, millions of dollars would have been spent.

In Tonga, koka (Bischoffia javanica) is preferentially retained on farms, and managed by pollarding to regulate competition with adjacent crops (PEDP 1985). Its deep rooting system allows ploughing and cultivation close to the trunk, and it provides a range of useful products including branches for yam trellises, good quality firewood and bark that is used to make a dye. However, methods for reproducing and replanting this species have not yet been developed in Tonga. For atoll environments, protection and replanting of coconut trees is likely to be the most effective way of enhancing biomass fuel supplies (PEDP 1986).

Adoption of Key Species for Planting on Farms

Given a good choice of tree species, and active management in locating the trees and controlling their form, it is possible to produce very substantial wood yields in farmland without reducing the yield of food crops significantly. Grevillea robusta has become the most important tree for planting on small farms in large parts of the tropical highlands of Africa (Harwood 1989). It is an exotic species native to Australia, introduced originally for tea shade, and not a nitrogen-fixer, but African farmers have adopted it because it is easily propagated and managed, and provides a range of useful products with minimal interference to cash and food crops.

Wood and food yields from a six year rotation of Grevillea robusta trees on farmland in Rwanda, country located in the highlands of central Africa, were measured by Neumann 1983). With 300 trees per hectare, 50 being harvested each year, annual wood yields from tree boles of around 5 M_3/ha and additional bough wood and prunings totalling about the same volume were achieved. The leaves from the trees felled on one hectare were sufficient to mulch 100-200 coffee bushes. Production of food crops was reduced by only 5 per cent, relative to treeless sites. Wood yields of this magnitude enable densely populated rural regions to be self-sufficient, and in fact to be net exporters of wood products, without drawing on natural forests or requiring land to be dedicated to forest plantations.

Trees provide a range of products and services, and fuelwood production, while important, is not usually the sole or primary consideration in selecting species and planting trees. In the African tropical highlands, small sawlogs and poles of Grevillea robusta and Eucalyptus species are sold, and the offcuts and smaller branches are used by the farmers for fuelwood. Along the central coast of Vietnam, Casuarina equisitifolia has been widely planted to stabilize moving sand dunes and thus to create and protect farming areas in marginal coastal land. Nitrogen fixation and heavy litter production enrich the soil. Poles and firewood from the species also provides an important cash income to rural people. Farmers sell their trees to wood merchants who split, dry and stack the fuelwood for sale at the roadside (Midgley 1990). In Thailand, farmers plant Cassia siamea, Sesbania grandiflora and Leucaena species for human food and shade; firewood is a secondary objective.

These examples show that farmers are capable of choosing the species they want and developing appropriate management techniques, often on their own accord or with minimum government assistance.

Manipulation of Spacing and Tree Form

Farmers sometimes grow trees in woodlots similar to small forest plantations, but more commonly farm trees are scattered through fields and planted in rows along farm boundaries, along terraces or around houses. Narrow, sparse crowns, and deep rooting systems with a minimum of aggressive lateral roots are characteristics that minimize the competitive influence of trees on adjacent crops. Farmers in many countries manipulate tree form by a range of methods including side pruning of stems, pollarding (chopping off large branches and the leading stem), coppicing (periodically cutting stems right off close to ground level), and even chopping off lateral roots by digging around the tree with a spade. This regulates the trees' demands for water, nutrients and light so that they do not lower crop yields to unacceptable levels. Tree species which recover well from such manipulation are often favored and adopted by farmers.

Land Ownership Patterns

Rapid growth of human populations leads to an increasing demand for food and fuel, and this is conceded by Westoby (1989) and Barnes (1990). However, Westoby argues strongly that deforestation, environmental degradation and fuelwood shortages arise primarily from inequitable patterns of land ownership and access to local resources. Landless people are forced into squatting on marginal land such as logged-over forest on infertile soils, where they cultivate inappropriate crops in unfamiliar environments, and collect and sell wood fuels and other wood products if commercial markets exist. The result is declining soil fertility, erosion and complete loss of tree cover. People are unlikely to plant trees and care for land unless they have ownership or secure long term rights to the land. It will be necessary to change inequitable patterns of access to farming land to resolve fuelwood shortages and forest depletion in some countries.

Selecting Tree Species for Farm Forestry in PICs

As noted above, promotion and protection of appropriate local tree species can be achieved by local farmers with minimal requirements for technical assistance.

Selecting exotic species for trial on particular sites requires an understanding of both the sites characteristics and the range of environments that the species can tolerate. New introductions are best done by experienced professionals, although there are many cases of farmers "adopting" exotic tree species that have been brought into a country for ornamental or shade plantings or forest plantations. Most PICS have very limited resources for testing exotic tree species for farm forestry Cameron 1986). Good indications of likely candidate species can be obtained from trials in larger countries with broadly similar climates and soil types. Boland 1989) reviews early results of trials of Australian species in South East Asia, China and east Africa. A practical guide to setting up trials of Australian tree species is provided by Carter (1987).

Exotic Versus non-exotic Tree Species

Forest plantations and agroforestry systems are highly modified environments, where tree are grown to meet human requirements. Farmers do not restrict themselves to indigenous food crops, and there is no logical reason why they should do so when selecting tree species for their farms. Certainly, if local species can be usefully integrated into farms then this should be done, but researchers and extension officers should not promote local species simply because they are local, if exotic species can do a better job for the farmer. The aim should be to have a range of useful species available for use on farms. This will minimize the effect of catastrophic pest attack on one tree species, as happened with Leucaena in PICs in the 1980s. The most important contribution to nature conservation made by trees on farms and fuelwood plantations is to reduce harvesting and clearing demands on the remaining areas of natural ecosystems, by providing a reliable alternative resource of forest products and sustaining the long-term productivity of farmlands.

Provenance Variation and Local Land Races

Wide-ranging species usually show considerable provenance variation. Seed taken from different natural provenances (i.e. different parts of the natural range) will yield trees that perform differently when the provenances are grown in a common environment. Once a species shows promise for farm forestry, gains in performance can usually be made by carrying out trials to determine the best provenance for use in a particular agroclimatic zone. As an example, Acacia auriculiformis shows great promise for agroforestry applications in the lowland tropics, being adaptable to a wide range of site conditions (Pinyopusarerk 1990). Some provenances of this species yield low, multi-stemmed shrubs while others yield tall, narrow-crowned single-stemmed trees that appear ideal for boundary plantings on small farms to provide poles, small sawlogs and fuelwood.

Many species have been established in exotic environments outside their natural range from very narrow introductions of only a handful of seeds from one or a few trees. This has often led to inferior performance of the resulting exotic "land races" of the species, because severe inbreeding from a limited genetic base reduces performance in subsequent generations. Fresh introductions of the species from the natural range usually grow much better than the land races, and it is therefore worth making the effort to obtain natural provenances when making comparative trials of exotic species. A. auriculiformis, for example, is known as a shrub of poor form in India, because the land race which has developed there does not represent the tall, vigorous provenances with good tree form that are now available from the natural range.

Soil Microorganisms That Improve the Productivity of Trees

Certain soil microorganisms greatly enhance the productivity of many tree species, especially on infertile sites. The relationship between microorganism and host tree is quite specific in many cases (see Baker and Torrey 1990).

Mycorrhizal fungi form symbiotic mutually beneficial) relationships with trees, by sheathing tree roots and improving their ability to take up soil nutrients). If the fungal symbiont is absent, tree growth can be greatly reduced. Grevillea robustu forms proteoid roots (enlarged, finely divided roots that perform a similar function to mycorrhizal root associations) without requiring the introduction of any symbiotic microorganisms from the species' natural range. This appears to be one of the reasons for its great success as an exotic in the tropical highlands.

Nitrogen fixing bacteria nodulate in the roots of certain tree species, and the nitrogen becomes available to the trees and later to nearby crop plants. Rhizobium bacteria associate with acacias, and Frankia with the family Casuarinaceae, which includes Casuarina, Allocasuarina and Gymnostoma species. There are many instances of casuarina plantings failing when no attention was paid to introducing the Frankia symbionts with the casuarina seedlings (Baker and Torrey 1990). Inoculation with a suitable strain of Frankia can give dramatic increases in productivity. In trials in south-east Queensland (Reddell 1990), inoculation of Casuarina cunninghamiana with Frankia more than doubled the wood volume at age 3.5 years, compared to uninoculated plants of the same provenance heavily fertilized with nitrogen, even though the inoculated plants were not given nitrogen fertilizer.

Similar studies on acacias and their associated Rhizobium symbionts have shown the importance of inoculation in improving productivity, and in some cases the specificity of the plant-bacterial relationship Roughley 1987). Acacias vary in their sensitivity - Acacia auriculiformis usually nodulates well with local Rhizobium strains while A. mangium often performs poorly (chlorotic yellowish appearance and slow early growth) unless a suitable strain is provided. The poor performance of Acacia mangium in a number of trials in PICs may be due to lack of suitable Rhizobium material (Cameron 1986). On infertile soils, low levels of added phosphorus fertilizer greatly improve the benefits of inoculation for casuarinas and acacias.

Supply of Seed of Exotic Tree Species

For over 25 years, the Australian Tree Seed Centre has provided seed of Australian tree and shrub species, technical information and training free of charge to PICs. In recent years this service has been funded by the Australian International Development Assistance Bureau through the "Seeds of Australian Trees" project. Those involved in fuelwood and agroforestry projects are welcome to write to the Centre for seed and advice.

Seed of species from other continents has generally been more difficult for PICs to obtain. ICRAF provides a worldwide guide to suppliers of seed of multipurpose tree species (Von Carlowitz 1986), and a second edition of this guide will be issued in the near future. The Nitrogen Fixing Tree Association (P.O. Box 680, Waimanalo, Hawaii) is a good source of information on suppliers of seed and inoculum for nitrogen fixing trees. Importers of seed should ensure that provenance details of imported seedlots are documented by the supplier and recorded by the user, and that all phytosanitary measures required by quarantine authorities are followed. Quality of tree seed is one of the most important factors affecting the success of tree-planting projects, and while it accounts for only a very small percentage of the costs of tree establishment, it is often neglected by project managers.

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THE DETERMINANTS OF THE URBAN ENERGY TRANSITION

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Introduction

In most LDCs pressure due to population growth and especially rapid urbanization is driving an energy transition which, in some cases, threatens to breakdown the traditional systems for woodfuel supply and use. The nature and process of energy transition manifests itself in varying forms for different groups and countries. For example, there has been a partial shift from firewood to agricultural residues and dung in many rural areas in Asia, Africa and Latin America where wood has become scarce. In this case, households moved down the "energy ladder".

However, in most cases, energy transition means a reduced role for bio-fuels and a growing role of modern, more convenient, often imported fuels such as kerosene, LPG, coal and electricity, for certain end-uses and/or income classes. The urban energy transition is a very dynamic phenomenon and progresses in different ways and by diverse means not only in different countries, but also within the same country for different cities.

The urban consumer in Asia and Latin America uses modern fuels such as LPG, kerosene, coal and electricity to a considerable extent. Urban consumers in Africa use less modern energy, and still rely to a great extent on woodfuels. However, even in major cities such as Rio de Janeiro, Asuncion, La Paz (also dung), Jakarta, Bangkok, and Beijing wood is being used by low-income households.

Urban consumers in many LDCs often do not use the cheapest fuels available to them. Despite the fact LPG and kerosene in many cases offer cheaper or equally priced solutions, the consumer prefers to use e.g. firewood, or to use a combination of fuels for different end-uses, which is the normal situation (see Tables 1 and 2). For there is no perfect substitutability between household fuels.

Factors Influencing Urban Fuel Transition

The reason why consumers display this apparent non-optimal behavior pattern is defined by the attractiveness of these various fuels. The "attractiveness" factors are the following:

(a) household size and income;
(b) access and availability;
(c) relative fuel prices;
(d) cash flow;
(e) equipment cost;
(f) convenience;
(g) cultural factors;
(h) appropriate equipment; and
(i) adequate information.

This listing is not an absolute ranking in terms of importance. The first two factors, access/availability and income, are both very important, while price and equipment cost are judged to be of lesser importance. In general, there is not sufficient statistical evidence to determine the relative importance of these factors in a quantitative manner. Time series data on comparable populations showing changes in these influencing factors and energy use are rare. Nonetheless, sufficient evidence is available to support general inferences about the relative influence of these and other factors. In what follows I will discuss these factors as they relate to cooking and lighting fuels. Electricity will not be discussed here, because it will be discussed in another panel.

Household Size and Income

The level of fuel consumption is determined by several factors, the most important of which are household size and income. The average per capita consumption figure is misleading. To accomplish a certain cooking task, a minimum quantity of energy is required. It takes less than double the fuel to cook in a bigger pot for twice the number of people. Where family size does increase with income, "economies of household size" may mask the overall increase in energy use with income, unless household size is also noted.

In general, higher income households consume a greater share of their energy needs from modern energy supplies. An urban survey from Colombia shows some of these patterns. The tendency for the high and middle income groups to substitute electricity for other fuels in cooking is clear; in the high income group, neither kerosene nor cocinol [a mixture of kerosene and gasoline] is used, while natural gas is not used by the low income households. Also, electricity and LPG use is higher in the high income households, both in relative and absolute terms. This relationship between income and fuel use is clear from Fig. 1, which shows that as purchasing power increased in urban areas of India, Pakistan and Brazil, the use of biofuels declined.

The general trend of increasing total household energy use with income is accompanied by both substitution of modern energy for traditional energy and increased modern energy use. The decreasing reliance on biomass fuels and resulting substitution by modern fuels is obviously more dramatic for the urban population, since access and availability of modern energy is greater in urban areas. For example, in Brazil in 1984, the rate of electrification in the major cities was more than 90%, while the corresponding rate in the rural areas was only 34% [Jannuzzi]. In Colombia the corresponding figures are respectively about 80% and 40% in 1986 [ESMAP-Colombia].

The relationship between income and energy use is obscured by household size and end-use efficiency. The more critical of these is end-use efficiency. If there is substitution of modern energy for traditional fuels, end-use efficiency is improving (kerosene and LPG stoves have much higher efficiencies than woodfuel stoves). Thus while effective demand for energy services (cooking, lighting, etc.) can increase with income, energy going into the household can actually decrease. This does not necessarily hold for low-income households, however. These often continue to use a combination of less expensive fuels for cooking and heating water. Also, they tend to restrict the use of their appliances. In this way, poor households ensure the availability of energy, but at the price of higher energy intensity.

Access and Availability

Access and availability of fuel supplies are very important considerations for a household's choice of fuel. Fuels that can be bought from the market at any time and in the quantities required, will clearly have an advantage over a fuel that occasionally disappears from the market or is only available in limited quantities, due to supply problems. After all, a consumer has to cook daily; therefore, reliability of supply and the presence of distributors are important elements of any household energy strategy.

However, for the vast majority of poor households i.e., the rural households, these traditional fuels (firewood, dung) are often 'free', or are available at lower financial cost than for urban households.

The differential access and availability of traditional fuels may stem from regional factors such as the relative closeness of state or community forests, or local economic factors such as ownership of resources. The resources yielding traditional fuels are trees/bushes, crop residues, and animal dung. Trees may be on state, community, or private land. Except in areas of plantation agriculture, crop residues will be private resources; the same is true of animal residues. Aggregate or even village average analysis can mask significant differences in ownership of resources and access to private or community resources, thereby masking differences in fuel choice options for different socio-economic groups. In other words, availability does not equal accessibility. The differences can even be a result of significant changes in resource characteristics from one area in a village to another, such as differences in land quality and/or elevation and hence, crop residue resources.

The patterns of growth of modern energy distribution systems exhibit enormous variations between and within LDCs. One of the few international constants is widespread electric power and petroleum product distribution systems in the capital cities and other major urban areas. Because of this, there is a tendency to use urban versus rural characterizations to describe this difference in access. However, care must be taken in pushing the urban versus rural description as a surrogate for access to modern fuels. Wide variations in access exist within the urban and rural sectors. For example, data for 1979 in Brazil show that the consumption pattern of rural households do not differ so much from low-income urban ones, which constituted 37% of total urban households [Jannuzzi].

Penetration Level of Modern Fuels in the Household Sector in Brazil

	Lowest income urban class	Average rural household
Petrol	3	11
LPG and city gas	39	27
Electricity	58	24
Fuelwood	74	77

The economics of energy distribution clearly favor large, concentrated markets, which is what cities in essence are. Later smaller markets (medium sized towns) are targetted. Political considerations may distort this picture, when for example, rural electrification projects become part of the energy distribution network. But even in this case, small towns and villages close to the transmission lines are more likely to be connected than those farther away.

Table 3 illustrates the importance of 'city size' and its effect on energy consumption. Biomass cooking fuels is the main fuel for both rural and urban areas for towns up to 25,000 in Sind and 100,000 in the Punjab (Pakistan). At the 200,000 population level all of a sudden substitution occurs (see the underlined numbers). In both provinces it is the largest cities which account for the bulk of the dwellings and population. Therefore, in view of both growth rates and fuel-switching behavior, it is likely that these large cities will have a major impact on future modern energy demand.

However, focussing on 'city size' only may be misleading. The case of urban Java is illustrative in this regard. An analysis of total cooking demand was done using the following three variables: "Wood availability, LPG availability and City size". When the analysis was done for 'city size' alone a very significant correlation between city size and energy demand was found [see figure 2]. However, when other variables, such as 'wood and LPG availability', were brought into the analysis it became clear that 'city size' was not as significant anymore (see Table 4). This suggests that city size, therefore, serves as a proxy for the 'availability' variable.

This also is borne out by the situation in Dhaka and Sythet (Bangladesh) where due to ready access to natural gas about 50% of the urban population uses gas instead of woodfuel for cooking. The unmetered and abundantly available supply of natural gas, high urban fuelwood prices and a policy of low gas prices has accelerated the transition from fuelwood to natural gas [Prior].

The availability of other modern household fuels--LPG, kerosene and coke--is a function of depots, distributors, and reliable supplies. General information on measures of access and availability of these fuels such as depots and dealers per population unit by region differentiated for rural and urban, LPG cylinders in circulation, district sales patterns by product, etc., is not readily available, yet are essential information for energy planning purposes.

A rather unique picture is offered by the situation in Colombia, where the differences in consumption patterns in the four major cities are quite different from one another. These differences can be mostly attributed to the availability of supply.

In Columbia, the urban household pattern of conventional fuel use was estimated by 1986 surveys as follows [ESMAP-Colombia]: Fuel use varies significantly by city and income class, and these differences can only be partially explained by the differences in fuel prices. Cocinol is the least expensive cooking fuel (though dangerous), but is only available in Bogota. Electricity is the next least costly energy source, but its limited availability to the lowest income classes restricts its use. Although not shown in the table, natural gas in currently available only in Barranquilla with a price of about US$5-7/per energy unit, once again underscoring the importance of the distinction between availability and accessibility.

City and Income Class	Household Energy Use mmBtu-useful				
	Electricity	Cocinol	Kerosene	LPG	TOTAL
Bogota					
lowest	0.29	0.63			0.91
middle	1.27			0.88	2.15
Baranquilla					
lowest	0.32		0.28	0.21	0.81
middle	1.55			0.04	1.59
Cali					
lowest	0.37		0.3		0.67
middle	1.02			0.07	1.09
Medellin					
lowest	0.82				0.82
middle	1.56				1.56
Stove efficiency	85%	50%	50%	70%	
Financial Price (US$) over energy unit	3.5	1	8.4	5.2	

A factor which adversely affects availability of conventional fuels is the difference in official market prices and relative shortages between rural and urban, or high and low income urban areas. In Rio de Janeiro, for example, "delivery of LPG bottles is unpredictable, poorly controlled and incomplete, and this means extra cost for the shanty town resident. This is primarily the reason why 25% of the income of households grossing less than the minimum wage per month is spent on energy" [Behrens]. In Lucknow (India), the poor segments of the urban population hardly use kerosene despite a 40% lower cost than firewood. The reason for this behavior is that they are deterred in doing so by kerosene shortages and long waiting lines rather than by the cost of the stove or other factors [Leach].

There is also back-and-forth switching between traditional and modern fuels due to supply problems and/or large price differences. In Sri Lanka, for example, many urban households switched back to the use of wood after a sharp rise in the price of kerosene in 1985 [Leach]. The fuel switching behavior even differs per end-use. For example, in Botswana "over the last two years, 11% of the sample switched cooking fuels, three quarter of them (8%) switching to gas and 2% to paraffin" (see Table 5). However, as far as lighting is concerned "only seven percent of the sample switched fuels over a two year period. The principal reason for this is the slow rate of electrification" (see Table 6) (ESMAP). A similar phenomenon was found in Zambia where the substitution between firewood and charcoal is mainly determined by the increase of the town size and can be linked to the urbanization rate. The substitution between electricity and charcoal for cooking is mainly determined by income, the availability of cooking appliances at a reasonable cost and the reliability of supply. In Zambia, due to high prices of charcoal during the rainy season of 1988, 33% of the urban consumers switched to the lower priced kerosene (23%), firewood (6%), electricity (1%), or to a combination of fuels (3%). After the rainy season they switched back to charcoal again, although kerosene was still cheaper. The reasons for doing so appeared to be the availability of charcoal nearby, the smell of kerosene, and old habits [ESMAP].

Petroleum products such as LPG and kerosene are marketed through formal markets, in particular through the oil companies' integrated supply network. LPG and kerosene retail sales are made through the oil companies' system. However, concomitantly there exists a unique distribution and marketing system in which "secondary" retailers dominate in low-income urban areas in many countries. These secondary retailers provide a service of breaking bulk volumes of commodities down to parcel sizes that poor consumers can afford, or provide LPG at credit. In addition, they sell their products where there are no formal market outlets, but at unofficial prices that can be twice as high as the official price.

Pricing Policies and Structures

The price of traditional fuels is important both in understanding the influences on substitution and for developing household energy strategies. The implicit price of firewood and in the rural areas can be measured in terms of the amount of household time necessary to collect fuelwood. In a rural environment, fuel switching (and demand reduction) occurs as a result of the implicit price. A rise in the implicit price is often associated with a deterioration of the rural energy system. The increasing demand for firewood leads to demand exceeding natural regrowth and this in turn leads to a need to travel further and/or spend more time collecting fuels or even to switch to dung and agro-residues. The switch to the latter and the depletion of wood resources can also lead to loss of nutrients and topsoil, and declines in soil productivity.

When traditional fuels have an explicit price, a major issue is whether this financial price is high enough to allow sustainable production. Often, firewood and charcoal prices are not high enough to allow profitable fuelwood plantations, or just rational natural forest cover management, because the financial prices are below economic prices. Thus local fuelwood as a cash crop cannot compete until market prices for urban prices include higher margins for producers and stumpage cost resulting in higher retail market prices. The same holds true, of course, for the price competitiveness of kerosene and LPG as substitute fuels.

Because there are no national markets for biomass fuels their prices reflect regional endowment and logistical differences. However, prices for substitute fuels, in general, have a uniform, subsidized price and thus, an often imported fuel unfairly competes with a national energy source. Even when there is a national market for biomass fuels, as is sometimes the case with charcoal, prices here also reflect regional differences as well as the real distribution costs.

Pricing policy with regard to modern household fuels is characterized by strong government regulation. Pricing policy rather than income policy is used by many LDC governments to achieve a better income distribution. As a result, prices of all household energy fuels, generally, are priced well below their economic cost. This not only leads to waste and inefficient use of scarce resources, but also has resulted in a heavy Government budgetary burden. It further has made pricing issues a socio-political issue which has lead to social unrest whenever changes are contemplated or implemented to reduce the level of subsidy.

The widespread use of electricity for cooking in e.g. Colombia and Costa Rica is both a function of its availability and price. The financial implications for the government and the supply companies are significant, the 1986 tariffs in Colombia, for example, were less than 20% of the estimated economic cost of electricity. The comparable figure for Ecuador is 40% and of Argentina 50%. The government's ability to adjust the prices of household fuels, therefore, is limited by its significant use at low prices.

Governments wishing to pursue an energy efficiency policy, therefore, will find themselves in a difficult position to achieve any meaningful results unless the incentive system under which rules the consumer operates is changed. This will require, inter alia, the governments to change the structure of relative prices as well as raise the prices of most, if not all, household fuels. This decision will entail a political choice between the issues of (a) biomass substitution; (b) equity issues; (c) revenue generation, and (d) the reduction of the 'free rider' effect. This last concept refers to the fact that any subsidy which cannot be limited to incremental consumers will be a free gift to those consumers who would have bought the subsidized good anyway, even in the absence of a subsidy.

Because of the low energy prices consumers tend to use energy inefficiently. Not only do people opt for less than optimal energy end-uses, but also use energy inefficiently. Prices not only may give the wrong signals to consumers, but also to energy producers and distributors. As a result production, refining, distribution and consumption decisions are not based on considerations that allow optimal and efficient use of resources. Governments can, of course, constrain availability and accessibility of household fuels, but this would run counter to their equity objective. For constrained supply will lead to higher prices for poor consumers. Governments need to reduce inefficient energy consumption to diminish the burden on the budget and balance of payments. Also, governments need to raise revenues to generate capital for investments needed for improved distribution systems, maintenance and increased end-use efficiency. However, raising all prices will also conflict with the equity objective. We have seen what even a marginal raise in energy prices brought about in Venezuela in March last year.

Options to deal with the issue would include (i) an increase of electricity tariffs for the high and middle income groups, but with life-line tariffs for low income households, (ii) making lower cost alternative fuels available, where necessary and possible (e.g. kerosene instead of LPG); (iii) marketing smaller (6 kg and 3 kg) LPG bottles for lower income households, as well as (iv) have an effective relative fuel pricing policy.

The cost of pricing distortions can be very high. The Bank recently has calculated that these cost in the case of Argentina have amounted to over US$3 billion over the last ten years. This would have been the additional revenue that might have been earned through: (i) increased gas and oil production; (ii) reduced waste of energy, and (iii) more efficient energy use.

Cash Flow & Equipment Costs

However, there are other economic factors that influence a consumer's choice. The retail price is only part of the investment decision that a consumer has to consider. Two other important elements are: the quantity of fuel purchased and the price of equipment.

Equipment costs are another important aspect of a household's fuel choice decision. Amortized over its lifetime, the cost of the cooking equipment (stove, LPG bottle) is a small portion (10-15%) of total energy costs. Nonetheless, the purchase price of the deposit on an additional LPG bottle is frequently beyond the cash flow capacity of low income households. As a result many low-income users are forced to purchase their LPG outside the regular commercial and cheaper channels. In informal markets, appliances often do not reflect minimum standards of energy efficiency and quality, there being no government rules and regulations for the import and/or manufacturing of energy efficient appliances in most countries. Also, poor households are forced by low incomes to buy cheap, often second hand, and thus less energy efficient appliances. Finally, appliances such as a kerosene stove are often bought at credit, where credit is available. For example, in urban Java, "travelling stove peddlers offer a variety of credit schemes, and return weekly or monthly for payments. While the implicit interest rate is likely to be as high as 150% per annum, this allows households to replace broken stoves even when they are facing a severe cash shortage". The main reasons that wood users in urban Java do not use kerosene is the high cost of the stove (22%) or of the kerosene itself (32%). It is revealing that the cost of the kerosene stove is felt to be almost as significant as obstacle as the cost of kerosene itself.

Convenience and Information

In addition to the factors discussed so far, convenience, storage, cultural factors, and market imperfections can also influence household fuel choice. The convenience of conventional fuels such as LPG and kerosene in providing heat quickly, as well as the ease of use, lack of dirt, and the lack of storage problems in comparison to woodfuels, contributes to their status as attractive fuels. To meet these convenience and preference wants, households may have to possess more than one type of fuel and appropriate stove. A summary of the main reasons why kerosene users in urban Java choose to cook with kerosene or LPG is given in tables 7 and 8. Almost 80% of the households cite the ease with which kerosene can be obtained or used and a similar pattern is found among LPG users. Most LPG users also claim not to use kerosene primarily because it is too dirty (41%) or too slow (33%). In short, they believe they are using a higher quality fuel.

Lack of information among consumers and suppliers, lack of market suppliers or other equipment, inadequate stove designs, and even lack of credit facilities to assist the market penetration are considered market imperfections that constrain fuel substitution. Consumers may not know of the higher efficiency kerosene stove which might allow them to shift and/or conserve fuels, and there might be no dealer actively pushing the stove in their area. In Brazil it was found that 'considerable energy savings could be made through a public information campaign". These market imperfections have long been recognized by marketers in consumer product areas, and by agricultural economists and engineers in the diffusion of new technology, inputs, and practices. Rarely have these barriers to the penetration of conventional fuels in the household sector been studied.

Conclusions and Policy Recommendations

If there is one conclusion that can be drawn from this cursory analysis of household inter-fuel substitution it is that we need more in-depth analysis of specific country contexts before definite recommendations can be made about the rate or scale of substitution fuels penetration that is economically feasible.

Another one is that there is a definite and significant correlation between urbanization and fuel substitution. Rising urbanization, combined with changing urban diets and cooking habits and the existing price differentials favoring substitution, likely will continue to drive interfuel substitution. Whether governments like it or not, this process will inevitably lead to a greater use of modern fuels.

Substitute fuel suppliers, in their turn, should realize that kerosene and LPG are not sold as fuels alone; they are sold as a service. This service entails stability of supply, a well-developed distribution network, safety in distribution and consumption, and an adequate supply of end-use technology. Substitute fuels cannot successfully penetrate the residential and commercial markets without attention to this notion of service.

This means that there should be easy access to substitute fuels. In many parts of the world smaller towns or poor sections of large towns are poorly served due to an inadequate distribution network. Where such easy access exists, as is the case in Indonesia, the majority of households use kerosene or LPG. In addition, care should be taken to avoid supply ruptures, which leads to hoarding of LPG bottles and higher prices as well as to high investment in back-up equipment due to back-and-forth fuel switching. The type of measures required here include:

(a) ensuring adequate level of stocks of fuels and of LPG bottles so that no supply ruptures occur; and

(b) expanding the retail network to the poorer sections of the urban areas.

The lack of low cost fuel devices also can be an obstacle for fuel substitution. Prices for devices are often high, due to high interest rates, and constrain substitution options for many poor families. Moreover, many of these devices are of low efficiency and quality, while there is little relation between price, quality, efficiency and producer type. These issues should be addressed along the following lines:

(a) ensuring quality in production of fuel devices and/or applying quality standards on imported devices and to create consumer awareness about quality and savings;

(b) introducing for sale 3 kg and 6 kg LPG bottles which are cheaper than the standard 12 kg bottles. This will overcome the cash flow problem of many households and reduce the transportation barrier due to the lower weight of these bottles; and

(c) establishing credit schemes for low-income households to overcome the cash-flow barrier of the high investment cost of fuel devices.

Current pricing policies associated with kerosene and/or LPG compound the difficulties of getting substitute fuels to the urban poor and the rural areas. Because kerosene or LPG is the most important petroleum product for the poor, it is often priced low at the retail level. This is generally achieved through a process of cross-subsidization, price controls, and low distribution margins. Because the structure of kerosene demand does not call for major gasoline stations or large outlays for costly real estate infrastructure, the margins to oil company wholesalers and primary retailers are kept low. The pricing problem is further compounded by the tendency in many developing countries to pursue uniform national pricing of petroleum products. Despite attempts in such a pricing structure to incorporate a transport component for movement of fuels to remote locations, it is generally designed that the oil supplying company has little incentive to market the product up-country.

The combined effect of these pricing policies on the unique structure of the kerosene market has been to discourage supply, aggravate scarcity, and raise kerosene prices at the secondary retail level by as much as 250% above the controlled primary retail pump price in urban and rural areas. These policies have not only failed in their objectives of not protecting the poor, but have aggravated the situation by leaving an important part of demand met only at very high prices. The only beneficiaries of a controlled price at the retail pump and wholesale level are the bulk breakers, or secondary retailers, and those diesel users who are able to access a lower cost alternative to diesel oil.

Suppliers, therefore, are reluctant to develop an adequate distribution network before they have a reasonable assurance that a feasible market exists for the substitute fuel. These problems can be lessened if the government is willing to provide a clear policy towards wholesale and retail prices, linking them to the economic cost of woodfuel to be replaced by the substitute fuel.

Governments therefore, should be willing to:

(a) price woodfuels at prices that reflect its eonomic replacement cost; and

(b) provide sufficient incentives for suppliers to develop the market for substitute fuels as well as a reliable distribution network.

Finally, market information may have a significant bearing on household fuel choices. Unless consumers are aware of what choices are available to them, they will not be able to make a well-informed decision. The same holds for suppliers who will not offer better equipment and services that would allow them to increase sales and profits in the fuel and fuel equipment market.

The energy sector in most countries absorbs a major part of public funds. As a result, parts of the system are reasonably well studied to support such investments and operational decisions. Conversely, household energy issues are not well understood. Development expenditures for the household energy subsector are therefore nearly non-existent. However, 'business-as-usual' substitution scenarios suggest that budget allocations and foreign exchange requirements can become quite burdensome. Also, that the benefits of such scenarios are often reaped by those who need them least. Whether governments like it or not, rising standards of living among urban dwellers, combined with changing urban diets and cooking habits, will inevitably lead to a greater use of modern fuels. By anticipating and directing the change in the fuel mix, fuel savings, and optimum allocation, stimulation of local industry can be achieved.

To play a meaningful role in the least-cost development of the household fuels market, it is necessary for both the public and private sectors in developing countries to develop and assess realistic market scenarios, which are based on currently available woodfuel resources, demand management options, substitution options, pricing policy issues, and are consistent with realistic expectations of growth in the country's economy and its financial resources.

Finally, there is not one single solution to the household energy crisis. Each country will have to find its own "solution," which more likely than not will be a mixed strategy i.e., the household sector will continue to use woodfuels, conventional fuels, new biomass fuels, and apply pricing policies that encourage conservation and interfuel substitution. Such a mixed strategy needs to produce the least-cost household energy supply.

Table 1: Percentage of Households Using Each Fuel by Urban Area Size

	Urban Area Size ('000 persons) <50	50-200	200-1,000	1,000+	ALL
ELECTRICITY	67%	75%	89%	95%	85%
Cooking	1%	2%	2%	4%	2%
Lighting	63%	74%	88%	94%	84%
TV	36%	42%	52%	62%	52%
Ironing	25%	34%	43%	56%	44%
Refrigerator	3%	5%	7%	18%	11%
Air Condition	0%	0%	0%	1%	0%
Pumping	3%	3%	5%	15%	9%
Wash Machine	0%	0%	1%	2%	1%
Econ. Ac	2%	3%	6%	8%	6%
KEROSENE	82%	91%	79%	93%	87%
Cooking	49%	76%	69%	91%	75%
Lighting	40%	29%	14%	6%	17%
Other	1%	4%	1%	0%	1%
LPG	1%	3%	4%	8%	5%
Cooking	1%	3%	4%	8%	5%
Water Heater	0%	0%	0%	0%	0%
BIOFUEL	55%	30%	25%	3%	22%
CHARCOAL	33%	40%	32%	17%	27%
Cooking	4%	2%	7%	0%	3%
Ironing	29%	36%	26%	17%	24%
Other AC	1%	3%	2%	1%	1%

Percentage base is the number of households in each urban area size category.

Source: UNESS 1988.

Table 2: Household Fuel Use by Urban Area Size

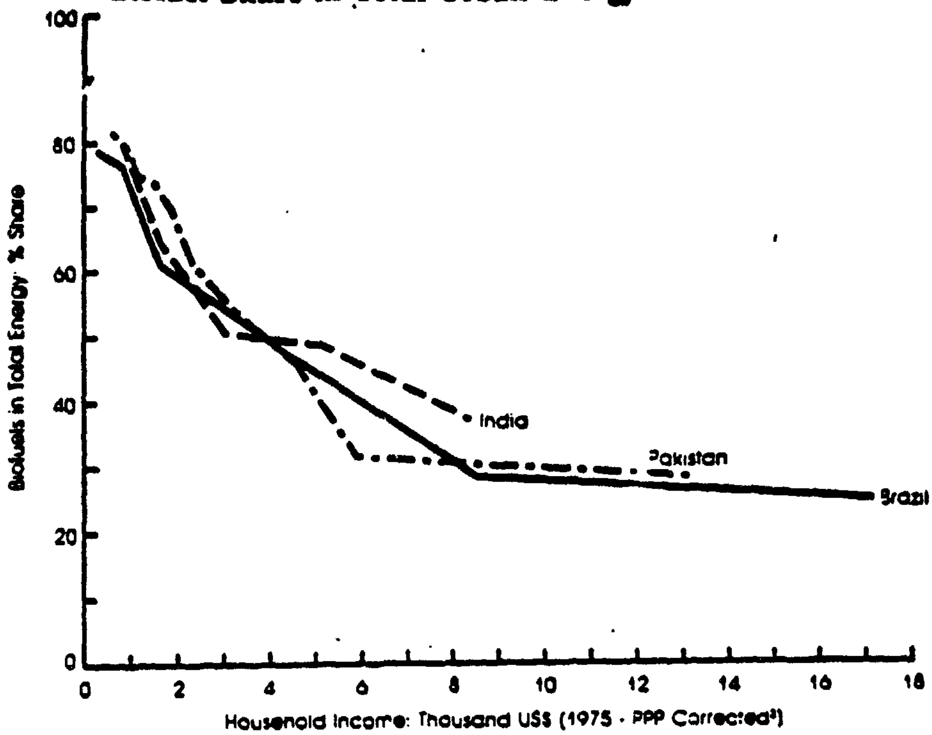
	Urban Area Size - 000 Persons <50	50-200	200-1,000	1,000+	ALL
ELECTRICITY-kwh/mo a/	22.1	32.3	38.6	78.1	51.5
Cooking	0%	1%	1%	1%	1%
Lighting	85%	75%	70%	42%	53%
TV	11%	11%	10%	8%	9%
Ironing	8%	9%	7%	7%	7%
Refrigerator	6%	4%	8%	12%	10%
Air Condition	0%	0%	0%	1%	1%
Pumping	3%	3%	3%	6%	5%
Wash Machine	0%	0%	0%	1%	1%
Residual	-13%	-2%	1%	22%	13%
KEROSENE-lt/day a/	0.8	1.0	0.9	1.2	1.0
Cooking	68%	83%	82%	91%	85%
Lighting	23%	13%	8%	3%	8%
Other	9%	4%	10%	6%	7%
LPG-kg/day	0.01	0.03	0.04	0.06	0.04
Cooking	100%	95%	91%	96%	95%
Water Heater	0%	5%	8%	4%	5%
BIOFUEL-kg/day	2.7	1.3	0.9	0.1	1.0
CHARCOAL kg/day a/	0.08	0.08	0.10	0.02	0.06
Cooking	31%	14%	41%	2%	27%
Ironing	49%	51%	38%	84%	51%
Other	20%	35%	21%	14%	22%

Percentages are breakdowns of mean fuel use of households in each urban area size category.

a/ Breakdown for electricity is based on a combination of survey responses regarding appliance wattage and use-levels, and statistical analysis of the relation between appliance ownership and electricity use of metered households. Breakdown for kerosene is based on direct physical measurement.

Source: UNESS 1988.

FIGURE 1 : Biofuel Share in Total Urban Energy with Urban Household Income



Notes: ¹ Includes energy consumption by household members and servants.
² PPP = Purchasing Power Parity

SOURCE: Gerald Leach and Marcia Gowen "Household Energy Handbook," World Bank Technical Paper No. 67. 1987

Table 3
Use of fuels for lighting and cooking by urban size: Punjab and ind 1980

Area or urban size	Percent Dwellings	LIGHTING Elec.	Kero.	COOKING Wood	Other Biom.	Kero.	Nat. Gas	LPG
All Pakistan		30.6	67.2	70.0	16.6	6.2	5.8	0.7
All Rural	71.76	14.7	82.7	78.6	19.9	0.7	-	0.3
All Urban	28.24	71.0	27.9	48.2	8.2	20.1	20.5	1.6
Sind								
Rural	56.0	10.9	85.8	85.8	12.6	0.4	0.2	0.4
Urban, population:								
under 10 k	1.6	49.5	50.0	90.8	4.1	0.9	1.4	1.5
10 - 25 k	3.4	52.9	46.3	88.5	4.2	2.3	0.9	2.8
25 - 50 k	2.5	67.9	31.0	71.4	5.3	5.8	10.9	3.8
50 - 100 k	2.0	71.4	27.6	57.3	5.4	7.3	25.6	2.5
100 - 200 k	2.6	76.5	21.5	62.5	4.5	3.4	24.4	3.4
200 - 300 k	1.1	68.2	29.2	18.0	1.0	44.7	30.9	4.4
over 300 k	30.8	69.4	28.7	23.0	2.6	32.9	37.1	2.3
Karachi Met.	(27.4)	67.9	30.0	21.2	2.4	36.1	36.3	2.5
Punjab								
Rural	73.9	13.6	85.8	76.1	22.5	0.8	-	0.3
Urban, population:								
under 10 k	0.5	47.5	51.8	61.6	21.8	6.3	8.1	0.3
10 - 25 k	3.2	54.5	45.1	75.8	15.0	6.9	1.0	0.7
25 - 50 k	3.1	64.8	34.8	72.9	9.9	10.4	5.1	1.1
50 - 100 k	3.2	65.6	33.9	70.7	14.4	7.8	5.2	1.2
100 - 200 k	3.3	70.0	29.6	66.4	10.1	9.2	12.1	1.5
200 - 300 k	1.4	82.9	16.0	49.0	10.7	21.2	17.0	1.4
over 300 k	11.5	82.4	16.6	36.3	9.6	24.6	28.0	0.7
Lahore Met.	(5.4)	86.9	11.9	29.0	8.4	33.4	27.6	0.7

Total dwellings (millions): Sind 2.782, Punjab 7.538
Pakistan (excluding FATA) 12.588

Source: Housing Census Report of Pakistan, Population Census ganisation. Data are for December 1980.

Urban Area Size and Cooking Fuel Use
Liters of Kerosene Equivalent

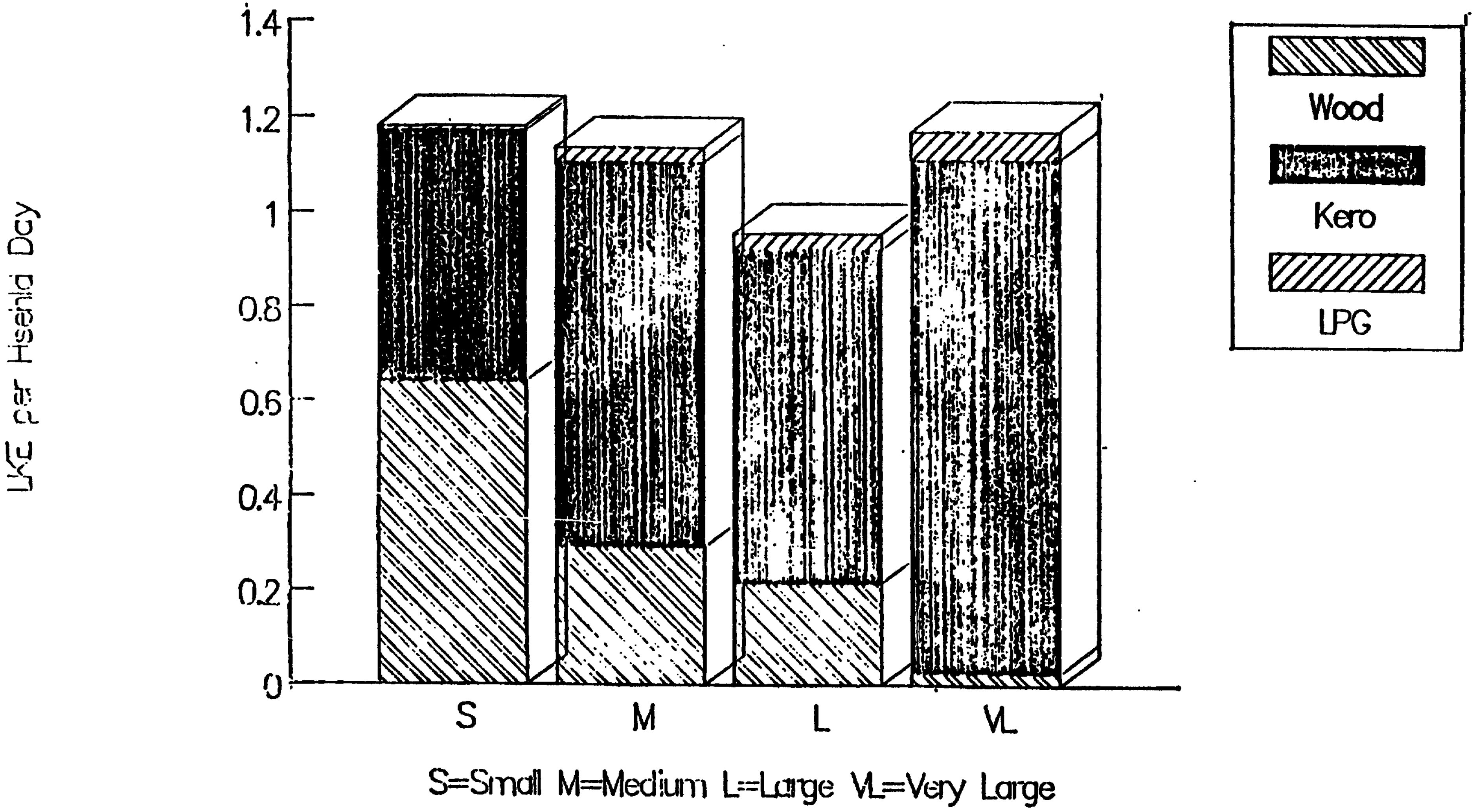


Table 4: Tobit Analysis of Residential Cooking Demand in Urban Java, 1988

MegaJoules of Daily Household Cooking Fuel Use by Fuel Type (MJ/HH/day)

Fuel	Fuelwood				Kerosene				LPG			
Expenditure Group	Low	Middle	High	All	Low	Middle	High	All	Low	Middle	High	All
Household Characteristics												
Family Size	7.48	11.48	2.79	7.63	1.07	0.92	2.35	1.55	-	-	1.78	2.46
	4.90	4.98	0.68	7.10	1.79	2.04	4.88	5.62	-	-	1.00	1.69
LN Expenditures/HH/Mo	-21.87	-65.78	-20.13	-29.37	14.17	11.74	-4.87	6.90	-	-	38.43	46.09
	-2.73	-2.73	-0.66	-7.90	3.69	2.07	-2.35	7.46	-	-	4.79	7.10
Fuel Price												
Wood Price (Rp/MJ)	-14.40	-6.32	-6.38	-7.59	0.45	0.41	-0.12	0.14	-	-	1.72	1.75
	-6.13	-2.76	-1.21	-6.16	1.46	3.10	-0.65	1.46	-	-	2.61	3.04
Charcoal Price (Rp/MJ)	0.88	-0.67	0.97	0.83	0.31	0.24	0.43	0.28	-	-	-2.65	-2.88
	0.77	-0.35	0.33	1.06	0.71	0.73	0.97	1.25	-	-	-1.48	-1.85
Kerosene Price (Rp/MJ)	15.39	17.15	4.38	12.58	-16.47	-3.14	-9.94	-8.99	-	-	2.66	-2.32
	1.05	0.81	0.12	1.26	-2.62	-0.86	-2.29	-3.86	-	-	0.19	-0.19
LPG Price (Rp/MJ)	7.87	24.13	-4.26	7.92	-2.28	6.99	3.01	1.90	-	-	-33.89	-44.92
	0.53	1.07	-0.11	0.71	-0.50	1.61	0.50	0.69	-	-	-3.77	-5.26
Electric Price (Rp/MJ)	0.02	0.57	-1.13	0.11	-0.21	-0.19	-0.29	-0.27	-	-	0.56	-0.12
	0.19	1.56	-0.48	0.87	-3.13	-2.37	-1.40	-5.91	-	-	1.03	-0.24
Fuel Availability												
Wood Availability	38.49	55.02	88.81	49.10	-11.51	-6.89	-3.87	-7.60	-	-	-0.05	-3.56
	8.52	6.69	4.80	13.33	-8.02	-5.97	-2.77	-10.18	-	-	-0.01	-0.91
LPG Availability	-8.61	-20.02	-29.02	-15.36	4.36	2.34	-1.70	1.60	-	-	20.11	21.31
	-2.54	-3.08	-2.60	-5.40	2.77	1.96	-1.03	1.95	-	-	3.45	4.17
LN City Size	-3.71	2.41	-2.79	-1.94	0.39	-0.75	0.21	0.38	-	-	-2.92	-2.34
	-1.79	0.59	-0.34	-1.07	0.43	-1.00	0.23	0.81	-	-	-0.90	-0.81
Cooking Habits												
Steam Rice	-0.78	-30.20	-18.57	-12.34	11.28	8.32	10.12	10.69	-	-	-20.07	-12.32
	-0.12	-2.71	-0.68	-2.15	3.95	3.37	3.37	7.27	-	-	-2.50	-1.66
Steam + Hot Water	6.23	-12.50	1.99	4.01	3.17	9.38	7.32	3.77	-	-	8.08	2.10
	0.71	-0.73	0.05	0.49	0.74	2.02	1.07	1.37	-	-	0.39	0.11
(Constant)	36.69	174.61	105.17	65.54	-18.06	-175.05	103.43	-34.76	-	-	-112.48	-40.24
	0.16	0.41	0.15	0.40	-0.22	-1.98	1.22	-0.85	-	-	-0.65	-0.28
Sigma	52.06	74.59	108.82	67.44	26.90	24.06	29.33	27.50	-	-	55.37	59.15
	45.58	17.31	11.41	50.61	50.26	65.34	75.11	134.62	-	-	10.72	10.83
Log-Likelihood												
@ OLS Stage	-3890	-3826	-372[illegible]	-11538	-3419	-3643	-3764	-10923	-	-	-3215	-8606
@ Convergence	-2058	-987	-48[illegible]	-3585	-2342	-3320	-3471	-9227	-	-	-755	-991
# Cases	790	815	805	2410	790	815	805	2410	790	815	805	2410
# Fuel Users	356	149	66	571	457	695	698	1850	4	22	108	134

Source: World Bank, 1990.

Table 5 : BOTSWANA: FUEL SWITCHING FOR COOKING - URBAN HOUSEHOLDS
Percentage over 2 years (1987/89)

Fuel	Switched from (%)	Switched to (%)	Net change
Wood	5.1	0.4	-4.7
Coal	0.1	0.1	0.0
Paraffin	4.2	1.7	-2.5
Gas	0.7	7.9	7.2
Electricity	0.7	0.7	0.0
Total	10.8	10.8	0.0

Percentage switched 2 years: 10.8 (5.4% p.y.)

Table 6 : BOTSWANA: FUEL SWITCHING FOR VARIOUS ENDUSES
URBAN HOUSEHOLDS 1987/89

	LIGHTING		WATER HEATING		SPACE HEATING	
% switched (2 years)	6.7%		1.4%		0.2%	
	FROM	TO	FROM	TO	FROM	TO
FUEL	PERCENT		PERCENT		PERCENT	
Wood	3	0	40	0	67	0
Coal	0	0	0	0	0	33
Paraffin	63	27	40	7	0	0
Gas	7	5	13	73	0	67
Electricity	1	45	7	13	33	0
Candles	26	23	-	-	-	-
Solar	0	0	0	7	0	0

Table 7: Attitudes Toward Kerosene for Cooking

Main Reasons for Cooking with Kerosene
(Households Using Kerosene for Cooking)

Kerosene is easy to get	48%
Kerosene is cheap	13%
Kerosene is easy to use	31%
Kerosene is clean	6%
Other	3%
Total Users	100%

Main Reasons for Not Cooking with Kerosene
(Households Using Other Fuels for Cooking)

Cooking Fuel Used	Wood	LPG	Either
Difficult to obtain	2%	0%	1%
Equipment expensive	22%	1%	15%
Fuel expensive	32%	14%	26%
Dirty	6%	41%	18%
Time consuming	8%	33%	16%
Unsafe	13%	2%	9%
Other	16%	9%	14%
Total Non-users	100%	100%	100%

Source: UNESS 1988.

Table 8: Attitudes Toward LPG

Main Reasons for Using LPG
(Households Using LPG)

Stove came with house	2%
Easy to get LPG	13%
LPG is cheap	14%
LPG cooks quickly	51%
LPG is clean	19%
Total Users	100%

Main Reasons for Not Using LPG
(Households Not Using LPG)

No distributor	16%
Road too narrow	2%
Equipment expensive	34%
Fuel Expensive	23%
Unsafe	11%
Other	13%
Total Non-users	100%

Source: UNESS 1988.

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IMPROVED COOKSTOVE PROGRAMS: EVALUATION ISSUES

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Introduction/Background

For a significant portion of the world's population, that is, for lower income groups in the rural areas of developing countries, there is unlikely to be a "spontaneous" and unsubsidized shift from biomass cooking fuels to fossil cooking fuels. This shift came without much external prompting in the presently economically advanced countries; since that shift occurred, however, the global economic and energy situation has changed almost unrecognizably (Smith, 1987). Recent world events and the subsequent rise in oil prices make that reality all the more obvious. The circumstances of those who depend on biomass cooking fuels cannot be ignored, not only because of the number of people involved but also because of the environmental and health effects that have come to be linked with existing patterns of biomass cooking fuel use. An intermediate-term response to prevailing conditions would be the development of biofuel production, conversion, and end-use technology. A short-term response has been the implementation of improved cookstove programs (ICPs).

In the close to fifty years that ICPs have been in existence, their circumstances and raison d'être have altered quite considerably. The first programs initiated were based on Gandhian thinking and had as their general objective the improvement of rural household hygiene and living conditions (Raju, 1953). It was much later that interest in achieving increased fuel utilization efficiency led to the design of improved cookstoves that used less fuel. These twin concerns for decreased household air pollution and increased efficiency continue to be expressed by small and large-scale ICPs in countries where biomass cooking fuels remain prominent.

Ongoing Programs

ICPs come in all sizes, colors, and shapes, sometimes even within a single country. Program activities may be limited to distributing small numbers of stoves within limited geographic areas. Their objective may be narrowly defined to improving fuel utilization efficiency within a certain group of households. And they may be implemented by small non-governmental organizations that perceive the dissemination of improved cookstoves as a component of their broader development activities. At the other end of the scale are national programs, that disseminate hundreds of thousands of stoves covering wide geographic areas. These programs often have multiple objectives and try to reach several socioeconomic strata. One must include in this spectrum, the activities of aid agencies, applied research groups, and bilateral projects. The objectives of these programs cover a wide range (Table 1), though the focus has traditionally been on fuel savings.

Table 1

Goals of Improved Cookstove Programs
(These include primary and secondary goals of various ICPs)

Increase fuel efficiency
Decrease smokiness in kitchens
Save time
Save money
Increase environmental awareness
Reduce deforestation
Community/institutional development
Improve status of women
Create jobs
Increase welfare of poor
Skill development
Generate income
Improve safety (reduce fire hazard)

The pattern of ICPs in the Pacific is different in that their scale is smaller and there have been few extensive government-sponsored programs. Still, given that wood and coconut wastes continue to be important cooking fuels in rural areas and kerosene in urban settlements, there have been efforts to promote more efficient kerosene and woodburning stoves (Siwatibau, 1981, 1987; Harwood, 1986). As with other regions of the world, there has been a combination of government-sponsored activities (e.g., Fiji) and small-scale initiatives by agencies such as the Peace Corps and by private concerns.

The number of improved cookstoves that have been disseminated number in the millions. In the People's Republic of China alone more than 99 million improved cookstoves are reported to have been disseminated between 1983 and 1988 (INET/INTEESA, 1990). Statistics from the Indian government's National Programme on Improved Chulas show that over a million improved cookstoves were disseminated in 1989-1990 (DNES, 1990). Other ICPs operate on a much smaller scale, with numbers of disseminated stoves ranging in the thousands rather than in the millions.

Evaluations and Perceptions of ICP Performance

What do all these numbers mean? What have ICPs achieved and what price has been paid to secure these ends? These are difficult questions to answer. Formal and systematic evaluations of ICPs have rarely been done in the past. The balance sheet on ICPs has more question marks than entries. One of the reasons for this is that monitoring and evaluation procedures are often not built into programs at their inception; instead these activities are carried out on an ad hoc basis GTZ/ITDG/FWD, 1990). Such practices, needless to say, make it very difficult to draw comparisons between projects. It also makes it difficult to make definitive statements regarding accomplishments of a given project.

This is not to say that no methodologies have been developed or that evaluations have not been done. FAO has just published guidelines for monitoring and evaluation in ICPs (Joseph 1990). These guidelines have been tested in the field by seven ICPs in six countries. These guidelines do present a framework for the evaluation process. They are expressed in general terms, however, and it was found that they could be and were interpreted variously. These experiences and the guidelines themselves provide an invaluable basis for the further explication and refinement of an evaluation methodology.

Evaluations of recent vintage show efforts are being made to systematically collect and analyze monitoring data from ICPs. These evaluations have been undertaken by various agencies under various circumstances. For example, the Institute of Nuclear Energy Technology and the Institute for Techno-economics and Energy System Analysis (INET/INTEESA) of Tsinghua University, Beijing, coordinated the evaluation of the Chinese ICP; the Department of Nonconventional Energy Sources in India asked three private independent research organizations to evaluate its program; and CARE'S ICP in the Sudan was evaluated at its request by three independent consultants INET/INTEESA, 1990; TERI, 1990; Kismul et al., 1990). The reports of these evaluations show that inspite of the increasing formalization of the evaluation process, uniformity or standardization in the procedures followed is still lacking. This makes comparison of results very difficult. Even for stove performance characteristics for which a measurement protocol exists and has existed for some time, a variety of procedures have been utilized.

To date, the primary indicator of ICP performance has been stove efficiency. Various tests and evaluation criteria have been developed for this indicator. Chief among these is the VITA protocol for testing the fuel utilization efficiency of woodburning cookstoves (water-boiling tests, percent heat utilization calculations, specific fuel consumption or kitchen performance tests) (VITA, 1985). ICPs often gather qualitative information from users regarding relative fuel use as well. Another indicator that is gaining widespread use is reduction of smokiness in the cooking area. While there are quantitative measures for this (Ahuja et al., 1987), most ICPs rely on qualitative field data to estimate achievement of this goal.

An additional difficulty of evaluating ICPs is one that is shared by all evaluations in general. There is a tendency to focus on those indicators that are relatively easy to quantify, to count that which lends itself to such attention. This is often done at the cost of developing indicators that may be equally critical to measuring the performance of ICPs but which are less easily estimated. Primarily these have been social and environmental indicators. In the eyes of stove designers and project implementers, these may not be considered critical indicators. If the effectiveness of ICPs is to improve, however, it is necessary to consider ICP characteristics that are important to all actors in the dissemination process--consumers, producers, project implementers, and donors. It follows, then, that more sophisticated indicators that address aspects of ICP performance other than improved fuel utilization efficiency must be developed. The need for these becomes apparent as many ICPs no longer limit their objectives strictly to achieving fuel savings. But monitoring and evaluation procedures have not caught up with these changes yet GTZ/ITDG/FWD, 1990).

EWC/ESMAP/UNDP Project on Evaluation of Improved Cookstove Programs

It was with these thoughts that the EWC/ESMAP/UNDP improved cookstove program evaluation project was initiated. The chief objective of this project is to develop an evaluation methodology that can be applied to make ICPs more effective in achieving their goals.

In Phase I, the project will have three outputs. The first is a global review of ICPs. The review will be based on available literature on ICPs as well as responses to a questionnaire survey that has been sent out to organizations and individuals implementing ICPs. This work is being supplemented by field visits to ICPs. In order to avoid duplicating efforts and to optimize returns, we are collaborating with the Foundation for Woodstove Dissemination (FWD: a networking Nairobi-based NGO) and the Association Bois de Feu (ABF: a French NGO active in the West African improved-stove arena) in conducting the survey.

In preparing the second output, a draft evaluation methodology, we are also coordinating our activities with Gesellschaft Technische fur Zusammenarbeit (GTZ: German aid agency) and the Intermediate Technology Development Group (ITDG: independent British appropriate technology group). A team of five has been assembled to prepare the evaluation methodology. In addition to the principal and associate investigators, consultants on administrative and programmatic evaluation, environmental economics, and stove technology will apply their expertise to review, summarize, and propose evaluation criteria. The draft methodology will be sent to members of the improved cookstove community for their comment and be revised accordingly.

The third output of the project will be terms of reference for a possible second phase in which this methodology will be applied to several ICPs.

Project status

The project is by no means complete (the completion date is February 1991). Our preliminary discussions, observations, and readings have led us to tentative general conclusions which are presented here briefly.

(a) ICPs have many different objectives but there are three common ones. These are fuel savings, smoke reduction, and time savings. Most ICPs have a combination of these objectives as their primary goal. It is more likely today than it was 20 years ago that ICPs will have multiple objectives. They are moving away from the trend of the 1970s and early 1980s when the explicit focus of ICPs was on fuel savings. This seems to be a response to two realizations: one, qualitative feedback from users in many ICPs has shown that fuel savings may not be the main or the only reason for adoption of improved cookstoves; two, establishing a causal link between ICP activities and the rate of deforestation has been discovered to be problematic even when fuel savings at the household level are evident. (In most cases, a decrease in household fuel consumption is difficult to demonstrate as well. The reasons for this lie in methodological issues which are discussed later on).

(b) ICPs may not be defensible solely on the basis of one objective, whatever that may be. They may, however, be justifiable when achievement of multiple goals can be shown.

(c) The operating time frames of ICPs and donor agencies may be at odds. ICPs are, by nature, longterm development projects. They may not be able to show the short-term results that projects with shorter time horizons are able to do. It would be a disservice to them to pass judgement prematurely or to truncate their activities.

(d) We have tried, at different times with various groups of people, to identify and define what constitutes fertile ground for ICPs. The result is one of the few points of consensus in our work so far. Among the key attributes of ideal sites for ICPs are invariably the following: a recognized fuel deficit; established markets for fuels and stoves; and established infrastructure for ICP administration. In other words, an urban area. What does this mean for the rural majority? Does it mean necessarily that there is no role for ICPs in rural areas? The answer to that question seems to depend greatly on the primary objective of the ICP and on program structure. If the main aim is to decrease the rate of deforestation, in many rural areas reforestation projects may be more appropriate than ICPs. On the other hand, if the project has multiple objectives which translate broadly to achieving an improvement in the quality of life, then an ICP may be a viable option, especially if the time horizon can be lengthened to more than two or three years.

(e) Apart from the inevitable bias toward the quantifiable, other methodological difficulties include standardization of procedures and their consistent application in widely varying circumstances. Even where procedures have been spelled out, as in the case of stove efficiency testing, confusion continues to reign. Which tests to use? What sample sizes? How should the samples be chosen? How to ensure prevention of bias in data collection?

Results obtained in different projects or even in the same projects over time are not comparable. Shown in Table 2 are efficiency test results for an improved cookstove and a traditional cookstove in south India. Both studies have used the same test--specific fuel consumption (SFC)--to determine efficiency. These tests were done in a single geographic area, possibly in the same households. The numbers obtained are quite disparate. What do they mean? There is really no way of telling because both studies assume that the SFC test is known well enough to make detailed descriptions of the procedure followed unnecessary. Yet there is ample opportunity for varied interpretation of the VITA protocol. For instance, the degree and extent of intervention by those conducting the tests can be critical to the results obtained. The instructions given to the cook, restrictions put on fuel usage, the presence of project staff in the kitchen when the test is being conducted, all affect test results. The purpose of giving this example is not to say that one method is right and the other wrong but rather to illustrate how variations in procedure can not only result in different answers but also make comparison and interpretation of results impossible. As with any other analysis, the numbers alone mean little.

Table 2

Comparison of Specific Fuel Consumption (SFC) Test Results

Stove Type	Sample Size	Mean SFC*	Standard Deviation	Coefficient of Variation	Source
Improved	40	365	146	0.40	Study A**
	150	209	58	0.27	Study B
Traditional	39	345	99	0.29	Study A
	20	400	105	0.26	Study B

* SFC is expressed as the grams of fuel required per kilogram of cooked food.
** Study A: Ramakrishna (1988)
Study B: Ravindranath et al. (1989)

Such considerations assume greater importance still when qualitative data are being collected. There are few set procedures to follow and often problems emerge at an early stage. Until quite recently, inadequate attention was paid to obtaining statistically valid samples. While one might argue that project staff cannot spend their scarce time and funds worrying about statistical niceties, ignoring them altogether spells disaster as well, particularly in large projects. Part of the problem could be solved simply by having a project staff member trained in statistical methods and data analysis so that monitoring and evaluation data can be gathered, analyzed, interpreted, and translated into program adjustments more effectively.

The improved cookstove is only one answer or one way of addressing the many, many problems ICPs are trying to ameliorate. There may be other answers which are more appropriate than improved cookstoves in certain situations. It would be helpful to reexamine the problems and the options and to keep sight of the fact that ICPs are only one of the many options. As a first step, we may need to broaden our outlook to view kitchens as workplaces instead of focusing narrowly on stoves.

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STOVES IN FIJI: AN EVALUATION OF THE JALEF DOMESTIC WOODSTOVE PROGRAMME

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Summary

The Jalef domestic woodstove programme was started in August 1984. The main objectives were: to increase the efficiency of woodfuel use and thereby reduce reliance on imported fuels, and; to improve general health conditions in the kitchens.

The Jalef stove was developed by modifying an already existing Fijian woodstove. The DOE selected the CATD (a Hanns-Seidel Foundation project) as the executing agency for the dissemination of the Jalef stoves. An EEC fund (65 000 ECU) was made available for the project, with SPEC providing the supervision. The dissemination project was set up as a self-help community programme, directed to the rural Fijian villages. In June 1987 the Hanns-Seidel Foundation decided to cancel the programme due to the following problems that had occurred during implementation.

To begin with the stove design had become far too complicated. There were great doubts about the stoves' performance in actual practice. No reliable laboratory tests had been conducted and it was found that the women did not use the stove as intended. Changing the traditional habits appeared difficult and operation and maintenance was rather complicated. To overcome these problems, an intensive and repeated training programme was proposed. Such a training programme was considered to be the responsibility of the women's organizations. However, they failed to coordinate their activities with the stove dissemination activities of the CATD, and, as a result, the users were hardly trained in how to operate the stove.

Secondly, the choice of the construction materials led to several problems. The concrete stove parts crack very soon after installation (it is not at all obvious that concrete is an appropriate material). To overcome these problems, metal stove tops were recommended. These however are very expensive and difficult to obtain, especially in the more remote villages. In addition the sheet metal chimney deteriorates very quickly, because of the salty, humid environment in Fiji, and the wrong usage and maintenance of the stoves. All these material problems led to a very short useful lifetime of the stoves (3 months to 3 years).

Thirdly, the training of the technicians and the villagers was too short for them to be able to build these stoves properly. As a result the construction and installation procedures were hardly ever followed. Moreover there was a general lack of motivation of tile technicians and the villagers to keep the stoves operational. These factors, in combination with the high costs (over F$70), made the stove inappropriate for dissemination.

To summarize, the following three factors caused major problems in the implementation of the Jalef stove project:

(a) Inappropriate stove design;

(b) Lack of quality; and

(c) Lack of training

The conclusion must be that the objectives of the project have only been partly met. Nevertheless, which has been learned from this experience regarding the necessary prerequisites for a successful woodstove programme.

It is recommended that, instead of rural woodstove programmes, more attention should be given to urban/peri-urban woodstove programmes, as there is a more severe fuelwood scarcity in these areas, and implementation should be less problematic. It can be concluded from the above that before starting a new programme three studies are necessary:

(a) An in-depth market survey;

(b) Development of a more appropriate woodstove; and

(c) A study on how to implement such a programme.

According to the author, there appears to be insufficient knowledge in Fiji to carry out these studies. It is, therefore, recommended that a stove consultant assist and train some local technicians, until such time as they are capable of undertaking this work independently.

Figure 1: Scheme for data collection

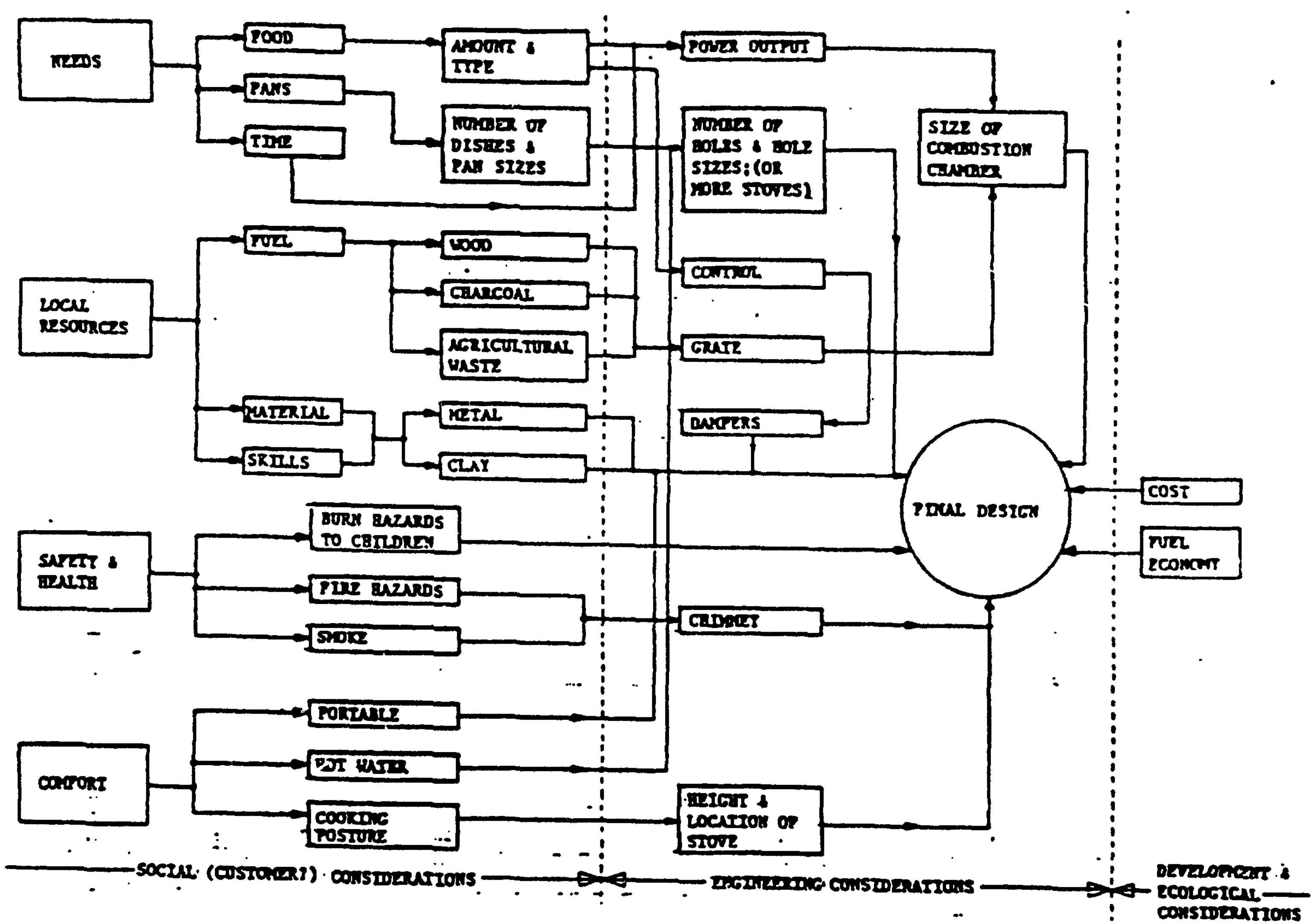
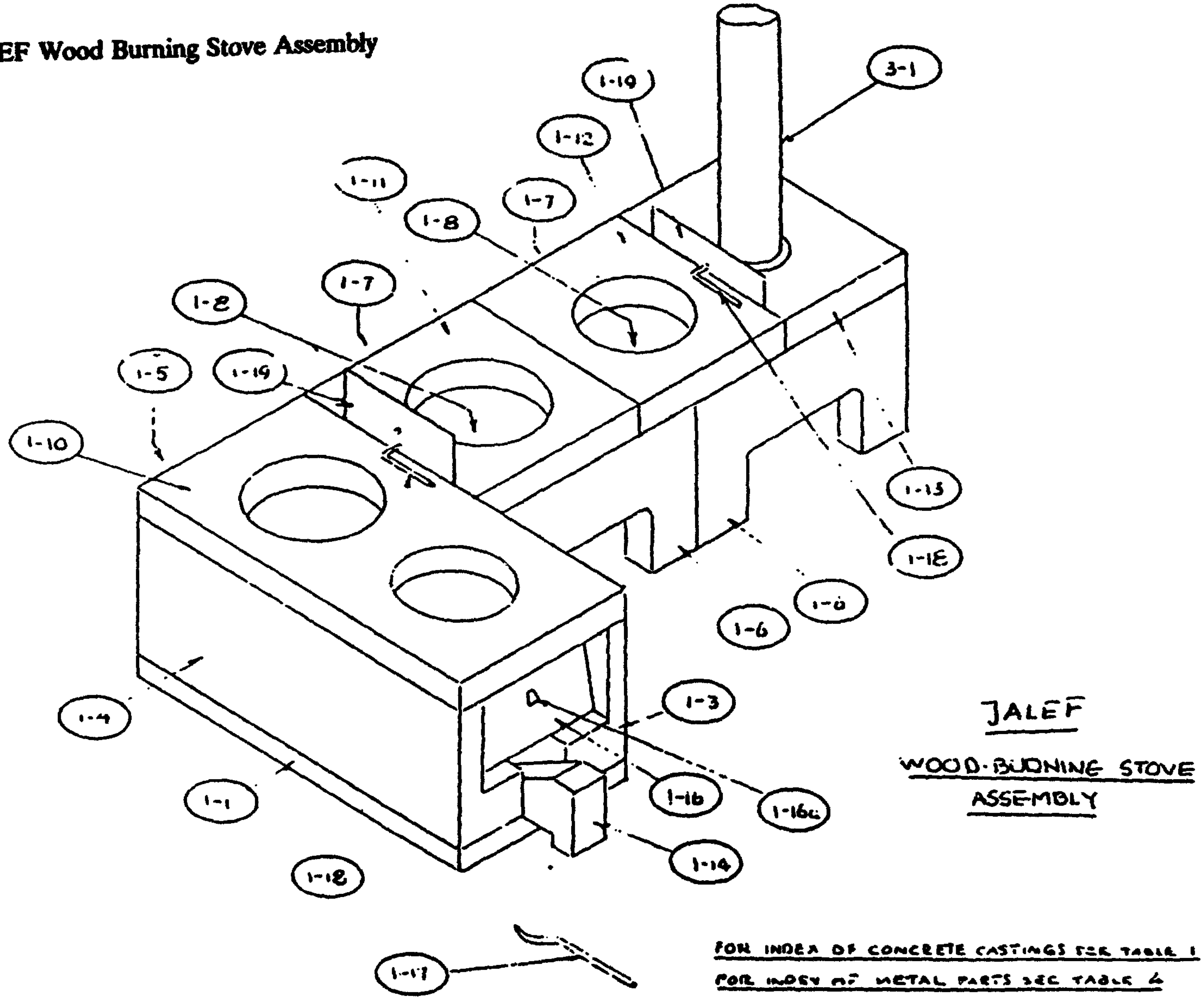


Figure 2: **JALEF Wood Burning Stove Assembly**



BIOMASS GASIFICATION FOR POWER AND PROCESS HEAT: THE PACIFIC EXPERIENCE

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Introduction

The history, basic principles, technology, and technical and economic potential of biomass gasification systems in developing countries have been widely documented by Foley and Barnard, Stassen, Mendis, to name a few. The World Bank has also published monitoring reports of gasifiers installed in Brazil, Burundi, Indonesia, Mali, Seychelles, and here in Vanuatu. The two applications of gasification technology, power gasifiers and heat gasifiers, have both been introduced to the Pacific Region. The Region, as used in this paper, represents member countries of the South Pacific Forum, (except Australia and New Zealand), and French and American territories where gasifiers have been implemented.

The independent island countries of the Pacific, which vary from large land masses to dispersed coral atolls, have had a history of dependence on imported fossil fuels for their commercial energy needs. The Region, as a whole, has a large potential in exploiting its renewable sources of energy such as biomass, hydro and solar, all of which are commercially proven technologies. This potential has generated a lot of interest amongst the island countries in attempts to ease reliance on imported fossil fuels.

Biomass, being a traditional source of energy, is expected to remain dominant particularly in rural households and institutions provided the fuel is sufficiently and cheaply available. The Region's search for alternative energy systems pointed to the direct combustion of woody fuels via gasification as a technology appropriate for utilizing a renewable source of energy to generate power and process heat.

History

The energy crisis of the 1970's, which revitalized biomass gasification technology, had adversely affected the Region's island countries. In the predominant agricultural sector, the cost of drying produce increasingly became a greater component of total production costs. Remote areas with diesel-based gensets were also hit by this crisis.

According to records with the Fiji Department of Energy, interest in power gasifiers in the Pacific emanated from the formation in early 1981 of the Gasification Implementation Unit (GIU) of Twente University in the Netherlands. The GIU'S prime objective was to introduce the technology to third world developing countries. Finance for implementing gasifiers in the Pacific was to be sought from the EEC funded Lome II Regional Energy Programme. Accordingly, 17 power gasifier projects were budgeted for 3,562,000 ECU and approved in 1984 for Fiji, PNG, Solomon Islands, Vanuatu and Western Samoa (see Table 1). With respect to heat gasification, PNG, Vanuatu and Western Samoa had in 1981 proceeded with the technology's implementation in their agricultural sectors for crop drying.

Table 1

Approved Lome II-Funded Power Gasifier Projects (January 1984)

Country	Gasifiers	Feedstock	Cost (ECU)
Fiji	10 x 10 kW dual-fuel sets	mainly charcoal	250,000
	1 x 10 kW	charcoal	250,000
PNG	1 x 300 kVA	sawmill offcuts	425,000
Solomon Islands	1 set for 160 kW diesel retrofit	sawmill offcuts	250,000
Vanuatu	1 x 50 kW	wood chips	117,000
	1 x 75 KVA	charcoal	230,000
Western Samoa	2 x 600 kW dual-fuel sets	coconut residues	2,040,000
TOTAL	17 gasifiers		3,562,000

Source: SPEC (1984) EEC Regional Energy Programme: Summary of Projects and Procedures. Circulated to ACP Member Governments, 15 February 1984.

The Region's association with biomass gasifiers dates back to the year 1923 when a coconut husk-fired gasifier was commissioned in French Polynesia to generate gas for a power plant. This gasifier system finally ceased operations in 1945. After a lapse of about thirty five years, the technology was revitali in many of the island countries as a means of utilizing sufficiently available biomass fuel resources.

Only two of the 17 gasifier projects approved for EEC Lome II funding were actually implemented; one each in the Solomon Islands and Vanuatu. These two power gasifiers however, were reduced both in capacity and cost relative to those originally proposed by pre-feasibility consultants. The non-implementation of the remaining (15) projects is thought to be due to the technology's unproven field performance which led to Regional Governments' preferences for other alternative renewable energy systems (e.g., PVs), envisaged fuel supply problems and the lack of local technically skilled manpower.

Gasifier Manufacturers

There are not any Regionally-based commercial manufacturers of biomass gasifiers. The power gasifiers installed in the Region were all manufactured externally by Biomass Energy Consultants and Engineers (BECE) of the Netherlands, Fritz Werner of West Germany, North-american Gasifier Corporation (NGC) of the United States, Pedrick of Australia and Fluidyne Gasification Ltd of New Zealand. At present, Fluidyne is the only active power gasifier manufacturer and supplier nearest to the Region. The other manufacturers have ceased business operations.

Waterwide Developments Ltd of New Zealand manufactured solid fuel burners for drying cocoa, coffee, copra, rubber and tea in PNG. Brugger Industries, a company of New Zealand origin, established operations in Western Samoa building hot-air generators similar to the "Waterwide" gasifiers for retrofitting to diesel-fired cocoa driers. Both Brugger and Waterwide companies are thought to have closed down their businesses as attempts to get in touch with them have been unsuccessful.

Power Gasifier Inventory

There were 17 power gasifier systems identified in the Region, of which two were financed by the EEC Lome II energy aid programme. The remaining 15 were purchased either through government initiatives or private dealings. A detailed inventory of power gasifier projects in the Region was recently compiled. This is discussed briefly in the following sections on a country by country basis. The inventory is summarized at the end of this chapter in Table 2.

Cook Islands

A "Fluidyne" down-draft wood gasifier was installed on Atiu Island for "experimentation" in March 1983. The dual-fuel gasification project was managed by two American Peace Corp volunteers who unfortunately, were thought to have little commitment to the gasifier. After some technical problems, the plant was refurbished in September 1983 by Fluidyne personnel which resulted in an improvement in plant performance. However, an injury to the wood saw operator's finger not long after this provided the excuse for ceasing gasifier operations! There was also no real incentive to keep the plant operating as it was externally funded. Additional factors thought to have contributed to the project's demise were fuel supply problems and a conflict amongst operators. The elder operators were reportedly not prepared to consult their younger counterparts who actually had a better understanding and capability of operating the gasifier. Since late 1983, the gasifier installation has remained inoperative.

Fiji

In 1984, the Fiji Electricity Authority (FEA) had the first "Pacific Class" woc gasifier produced by Fluidyne (New Zealand) installed at the FEA premises in Vuda. The pla.. was run under different operational conditions using various wood fuel species for demonstration. According to Mr. John Pirie (Chief Engineer, FEA), the trial runs had shown the gasifier to be "uneconomic due to excessive operator attendance requirements in comparison to equivalent diesel sets". This finding unfortunately, was virtually the end of Government's gasification interests.

The only other known gasifier in the country was donated by the Australian High Commission to the University of the South Pacific in 1985. This charcoal-fuelled "Pedrick" gasifier was last used in 1987 by Physics undergraduates for energy-based laboratory experiments.

French Polynesia

Two 60 kW "Winthertur" generators on Papeete were fed with "weak gas" by gas-generators operating with coconut husks between 1928 and 1945. A 190 kVA dual-fuel "Delacotte" fixed bed down-draft gasifier was installed in Bora Bora in 1978 which had, by 1984, recorded only 2,500 operational hours (op. hrs). Electricity of Tahiti, a private company, attributed the Delacotte's disappointing performance to "the peculiar socio-economic characteristics and manpower situation on the island leading to a lack of biomass fuels".

In 1984, the South Pacific Institute of Renewable Energy (SPIRE) developed a "Chevet" coconut waste-fuelled gasifier which was later installed in Raiatea. By 1985, this plant had clocked 1,200 op. hrs. Both the Delacotte and Chevet gasifiers are however, currently inoperative due to recurrent technical difficulties and fuel supply problems. These installations are now supplied with power from liquid-fuelled generators.

Mariana Islands

A charcoal down-draft gasifier, supplied by NGC, was installed in Saipan. No other technical information is available but, technical problems requiring spare parts and service personnel reportedly caused the suspension of gasifier operations. This was exacerbated by the closure of NGC and the unavailability of skilled technicians to carry out proper maintenance.

Palau

An agricultural station in Nekken was also provided with a 15 kW "NGC" gasifier in September 1984. The difficulties faced by its sister plant in Saipan (Mariana Islands) were also experienced in Palau, leaving the gasifier in its current idle state.

Papua New Guinea

A 20 kW "Fritz Werner" wood gasifier was installed in June 1983 at the Numondo Plantation in West New Britain Province. Tar condensation along the gas lines soon after commissioning developed serious technical problems which the manufacturer had hoped to solve by adding a bag filter. During the course of refurbishing however, Fritz Werner closed down (in 1985) its business operations. The gasifier is now obsolete.

Two Fluidyne-made Pacific Class gasifiers were commissioned in 1987 at the Lapeigu Sawmill in Eastern Highlands Province to generate power from sawmill residues. The gasifier systems were then transferred to the Yoru Sawmill in Madang Province after the ELCOM grid was extended to Lapeigu. The plants however, have not operated to date owing to prevailing financial difficulties at Yoru.

Pitcairn Island

One Pacific Class gasifier was installed in 1987 on Pitcairn Island. The only report received from the island not long after commissioning revealed diesel savings of up to 900 liters per month, which in their situation was substantial.

Solomon Islands

The only gasifier on record in the Solomon Islands is a 15 kW "BECE" charcoal down-draft gasifier. The EEC Lome II-funded gasifier was commissioned at the Batuna Sawmill, New Georgia Group, in November 1987. Charcoal for feedstock is produced locally using sawmill off-cuts. The gasifier was proposed to generate electric power for a fish storage plant and an ice machine. However, frequent breakdowns attributed to inferior gas cleaning and cooling systems caused the management to revert to existing diesel plants for power needs of the refrigerator and ice maker.

Vanuatu

Four power gasifiers are known to have operated in Vanuatu. The earliest gasifier, a charcoal cross-draft unit which had an output of about 20 kW, was coupled to a 3.8 litre Toyota Landcruiser petrol automotive engine. This unit was installed in the 1970's at the Kristian Institute of Technology of Weasisi (KITOW) on Tanna Island. The gasifier was operational for several years until the departure of expatriate staff who were involved with its design and construction.

The remaining (three) power gasifiers were all installed at the Onesua High School on Efate Island. In 1981, an expatriate operator modified a Fluidyne gasifier which consisted only of a fuel hopper and a gas making hearth. The unit's unsatisfactory performance led to the construction of another gasifier, utilizing locally available materials. This latter project, funded mainly by the Commonwealth Fund for Technical Co-operation (CFTC), was coupled to a second-hand 4 litre Toyota Landcruiser petrol engine and had an electrical output of up to 25 kW. Unfortunately, CFTC funding was withdrawn at a stage when the gasifier had just begin to operate intermittently.

Owing to the above experience, and the availability of a skilled technician and ample wood fuel resources, Vanuatu was allocated with a 25 kW "BECE" down-draft wood gasifier through EEC Lome II aid funds. The gasifier was installed in December 1986 at Onesua to generate power for the school and community. A "leucaena" fuelwood plantation was also established to supplement future feedstock needs for the gasifier. On record, the gasifier has proven to be a workable unit in spite of the major repairs done to its reactor whose original refractory was replaced with a special steel casting in December 1988. The plant is currently in operation.

Summary of Power Gasifier Operation

Eleven of the seventeen power gasifiers identified in the Region are now obsolete. The others are currently not in use due to technical difficulties except for the unit in Vanuatu which is still operational. The failure of the now obsolete gasifier systems is largely attributed to the following factors:

(a) technical flaws in design;

(b) difficulties in locating spare parts;

(c) closure of manufacturing businesses;

(d) fuel supply problems;

(e) unavailability of technically skilled manpower;

(f) lack of commitment of operators and management towards gasifiers.

Table 2 presents a summary of past experiences with power gasifiers in the Pacific Region.

Table 2

Summary of Power Gasifiers in the Pacific

Country	Make	No.	Fuel	Year	Current Status
Cook Is.	Fluidyne	1	W	1983	Non-operational
Fiji	Fluidyne	1	W	1984	Demonstration
	Pedrick	1	C	1985	Non-operational
French Polynesia	"Withertur"	1	H	1928	Non-operational
	Delacotte	1	H/D	1978	Non-operational
	Chevet	1	H	1984	Non-operational
Mariana Is.	NGC	1	C	ina	Non-operational
Palau	NGC	1	C	1984	Non-operational
Papua New Guinea	Fritz Werner	1	W/H	1982	Non-operational
	Pacific Class	2	W/D	1987	In abeyance
Pitcairn Is.	Fluidyne	1	W	1987	ina
Solomon Is.	BECE	1	C	1987	Not in use
Vanuatu	"local"	1	C	1970s	Non-operational
	Fluidyne	1	W	1981	Non-operational
	"CFTC"	1	W	1981	Non-operational
	BECE	1	W	1986	Operating

Fuels: C - charcoal, H - coconut husk, W - wood, D - Diesel (dual-fuel)
Note: ina - information not available.

Heat Gasifier Inventory

In terms of number installed and degree of success attained, heat gasifiers have been more successful than power gasifiers in the commercialization of gasification technology in the Region. Heat gasifiers or hot-air generators were widely used for crop drying, during the early

1980's in copra, cocoa, coffee, tea and rubber plantations in three countries namely, PNG, Vanuatu and Western Samoa.

Papua New Guinea

High diesel prices and depressed agricultural commodity prices prompted plantation and fermentary managers to seek alternative low-cost solid fuel biomass. Traditional Indian wood-fired "Sirocco" air heaters were introduced in the 1960's, some of which are still operational. Since 1981, 80 "Waterwide" gasifiers were installed throughout PNG mainly in the Western Highlands' tea and coffee estates and in cocoa and copra plantations near Rabaul and on Bougainville.

Waterwide direct-fired burners first started with the model DF70 (67 units installed) which was superseded by models DF75, DF145, DF35, HE70 and EHD70. These burners were installed both as stand-alone systems and as retrofits to diesel-fired flat bed driers. The distribution of Waterwide gasifiers amongst the five agricultural commodities processed in PNG is given below in Table 3.

Table 3

Distribution of Waterwide Gasifiers in PNG

Industry	Cocoa	Copra	Coffee	Tea	Rubber	TA
No. of Waterwides	38	20	11	10	1	80

Not long after installation, the Waterwides were found to have had reduced total production costs quite significantly. In 1985 however, the burners were noted to produce smoke if they were not managed properly, adversely affecting the quality of cocoa and coffee beans. Due to the growing number of such installations, the amount of rejected dried beans increased significantly. Smoke contamination, seen then as a very serious problem, was thought to be caused by the presence of smoke in the hot air and flue gas mixtures in direct firing. Work procedures observed by the PNG Department of Minerals and Energy as having contributed to smoke contamination are as follow :

(a) any solid fuel burner would normally produce smoke during start-up

(b) fuelwood was fed when the first load had exhausted leading to more start-up cycles

(c) the manufacturer's recommended 20 minute fuel feeding cycles were not adhered to by operators

(d) failure to have a good fire meant having low temperature profiles in the burner, which allowed tar and similar compounds to bypass thermal cracking reactions

(e) moist wood was used for combustion

(f) thick layers of fermented moist cocoa on the drying beds caused a back pressure on fans, reducing both the fan output and capacity of the desired amount of air through the burner.

To eliminate smoke contamination, most fermentaries had retrofitted heat exchangers to the Waterwides in spite of the heat exchangers' higher cost and lower efficiency. A couple of fermentaries in Rabaul have reverted to conventional diesel-fired drying systems. In February 1990, the author inspected 37 Waterwide burners (out of 80 installed) of which 18 were still used, mainly for drying copra and withering fresh tea leaves.

Vanuatu

No accurate inventory of heat gasifiers is available but some information on the technology's history in Vanuatu was obtained from a World Bank (1985) Report. It was reported that Government introduced a programme to improve copra quality by using hot-air generators that not only produced high quality copra, but also required less fuel input. By the end of 1983, hot-air dried copra comprised 15% of total production. The current status of these heat generators is not exactly known. However, they are believed to have phased out owing to wear, and the fall in national copra production.

Western Samoa

An exact inventory of "Brugger" hot-air generators in Western Samoa is also unavailable. In the early 1980's, Brugger Industries started building burners locally for retrofitting to diesel-fired rotary cocoa driers. Similar to Vanuatu's heat generators, the current status of Bruggers is not known.

Summary of Heat Gasifier Operations

Heat gasifiers have had a more successful operational history in the Region than power gasifiers. Their wide usage for drying agricultural crops in PNG, Vanuatu and Western Samoa were initially advantageous with respect to diesel fuel savings and dried crop quality. However, significant technical problems eventually outweighed the benefits previously enjoyed by plantations and fermentaries. The problems have now left most of the heat gasifiers to be no longer in use.

Availability of Biomass Fuels

Many surveys, including the Pacific Energy Programme Mission of 1980/81 and the World Bank's Energy Assessment Programme of 1982-1985, found biomass fuels to have a large potential in the Region. Coral atolls, such as those in Tuvalu, and some peri-urban areas on bigger islands are known to be facing a scarcity of biomass fuels. Reforestation and coconut replanting schemes have been implemented widely but have had mixed success. Coconut wastes are thought to be decreasing in supplies due to depressed copra marketing conditions.

The larger island countries namely Fiji, PNG, Solomon Islands, Vanuatu and Western Samoa have access to wood from natural forests by means of logging, land clearing activities and sawmilling residues. Biomass fuels from such sources are thought to be sufficiently available for gasification systems. The unavailability of wood fuel however, has often resulted from the absence of any formal schemes to collect the scattered fuels and the non implementation of tree replanting programmes. Land ownership problems also tend to contribute to difficulties in accessing biomass resources.

Charcoal is also available in some countries but is mainly consumed domestically, such as for barbecues. Crop residues are largely used by the estates themselves for heating, road filling, and as a mulching medium in gardens. Overall, acceptable biomass fuels are sufficient for gasification needs in most of the bigger island countries provided the available wood fuel is collected schematically, consumed economically and regenerated.

Economics

The replacement of diesel-fired driers with wood-fuelled heat gasifiers had drastically reduced total production costs within the agro-processing industry. In PNG, for instance, Waterwides in two tea plantations had fuel costs reduced from K110 per ton of made tea (MT) with diesel firing to about K33/t MT with wood burning, which gave annual fuel savings in the order of K150,000 for a typical throughput of 2,000 t Mt/yr for a capital outlay in the vicinity of K50,000 (Gilmour 1987).

Power gasifiers however, did not operate long enough to a stage where savings from the switch to low-cost biomass could be realized. However, studies of the Onesua plant found that an initial diesel saving worth about US$7,000 was made during 1987, the first full year of operation.

Environmental Issues

Gasification systems in the Region have had no record of creating any major environmental problems. Wood-fuelled energy systems are usually linked to eventual deforestation and soil nutrient depletion if wood consumption exceeds regeneration. The disposal of solid wastes from gasifiers, primarily ash residues, is not a problem. In the case of heat gasifiers in PNG, the residues are used as a mulching medium in plantations and also for resurfacing paths.

The charcoal gasifier in Batuna (Solomon Island) has in fact, done good to the local environment. Sawmill wastes, which usually were discarded by means of incineration and disposal into the sea, are now being burnt to produce charcoal. The Onesua (Vanuatu) plant is considered to be environmentally constructive following the establishment of an energy plantation. Residual ash and condensates from the above gasifiers are not a problem. Hence, detrimental effects to the environments of Regional gasifier installations are considered minimal.

Safety Aspects

A few cases of fires and toxic gas emissions were reported in PNG. One copra plantation was reported to have had two fires in its driers due to the interaction between coconut oil and sparks from the burners. One coffee factory had two of its workers hospitalized due to poisoning by toxic gases emitted by Waterwide heat gasifiers. Gasifier installations in other Regional countries however, have had reasonably "safe" operational records. Safety hazards can be eliminated if gasifiers are operated properly following suitable practices under an able management. Ample ventilation is also vital for the safety of operators in gasifier installations.

Social Acceptability

The successful operation of heat and power gasifiers would normally be beneficial to end-users due to "cheaper" and improved heating processes and grid-remote dwellers having access to low-cost biomass-fuelled power supplies. Heat gasifiers in PNG, Vanuatu and Western Samoa were operationally satisfactory not long after commissioning, but technical problems eventually outweighed the advantages of the technology.

Power gasifiers installed throughout the Region have had a lower degree of acceptability to managers, operators and end-users owing mainly to recurrent technical difficulties and the fact that the technology usually involves more tasks relative to conventional energy systems' manpower needs.

Summary of the Pacific Experience

The most successful commercialization of gasification technology in the Pacific Region has been with small wood and husk-fuelled heat gasifiers, as particularly proven in PNG. The technology's potential was thwarted however, by smoke contamination problems which had adverse effects on processed agricultural produce. Power gasifiers, the second half of gasification technology, were introduced more widely in the Region but had a lower degree of success in terms of system performance. Although the biomass resource bases in most of the island countries are adequate to demonstrate its potential to provide gasifiers with low-cost fuels, opportunities for the commercial use of the technology is limited due to usually high initial capital costs, the unavailability of technically skilled manpower and the generally disappointing experiences with gasifiers in developing countries.

CASE STUDY: ONESUA WOOD GASIFIER

Background

A 25 kW "BECE" wood down-draft gasifier, funded through the EEC Lome II Regional Energy Programme, was commissioned in December 1987 at the Onesua High School (56 km from Port Vila) on Efate Island in Vanuatu. The school, which is operated by the Presbyterian Church within the Vanuatu education system, has about 300 full-time boarding students and 100 staff and family members. Prior to the gasifier's installation, electricity for the school community was generated by a three cylinder "Lister" diesel-based alternator capable of delivering about 25 kW. This Lister is now maintained as a back-up to the wood gasifier. The school's power demand was estimated to be approximately 20 kW (peak). A trial fuel plantation of 4 ha was established in 1986/87 for supplementary wood supplies and to ensure a secure supply of fuelwood for the gasifier.

This case study is based on the gasifier's operational performance during the 23-month period from January 1987 to November 1988 (BASE CASE). The input data was obtained from a fellow consultant who later published an Operational Draft Report of the gasifier for the World Bank in February 1989 (see Table 1). The economic viability of the system has been studied by calculating the cost per kWh for gasifier generated electricity compared with the cost of the Lister's diesel-generated electricity (see Table 2). The economic analysis follows the principles given in Stassen's "Economics of Small-Scale Biomass Conversion Systems" (Training Course on Energy Management in Small and Medium Scale Industries, Twente University, the Netherlands, 10 October - 9 November 1989).

Input Data

All calculations are based on data gathered by operators when the gasifier was running. The analysis does not take into account the cost of operating the Lister diesel back-up during gasifier outages. Forestry costs attributed to the new energy plantation are included in the analysis as they were incurred after the commissioning of the gasifier. For a comparative economic analysis, operational characteristics of the gasifier and those assumed for the Lister set are given below. All costs are given in the Vanuatu currency, Vatti (Vt), whose exchange rate in January 1987 was Vt 115 = US$1.

(a) the capital cost of the gasifier is not taken into account as it was externally funded. Similarly, the Lister's capital cost is excluded since the diesel genset is more than ten years old and assumed to have fully depreciated. For informative purposes, the gasifier had a total cost of Vt 12,681,314 while an equivalent diesel plant was estimated to cost about Vt 3,020,000. These costs include PIF, installation, building, port handling, training and drawings.

(b) the installed capacity of both the gasifier and Lister is 25 kW.

(c) the expected lifetime of the gasifier based on "normal" usage is 20 years. During this time it can be expected that at least some of the components of the engine will be required to be replaced. These costs have not been included in this analysis.

(d) with respect to operational time, the gasifier and Lister are compared for the same number of operational hours per day, and at the same average kW loading. The gasifier had operated for 4,958 hours to the end of November 1988 producing 56,640 kWh of electric energy, equivalent to an average loading of 11.4 kW. The duration of gasifier operations during this period was 650 days, averaging 7.6 op. hrs/day.

(e) the fuel consumption of the gasifier was 123.5 t of wood, equivalent to 2.18 kg/kWh or 24.9 kg/op. hr. The Lister is assumed to consume 0.4 1/kWh.

(f) the fuel cost for the gasifier feedstock was taken as Vt 8,000/t. being the cost of fuel for transportation and sawing implements, and forestry costs for the newly established energy plantation. Diesel cost is taken as Vt 50/l.

(g) the labor costs for running the gasifier installation were calculated to be:

(i)	operation and maintenance by unskilled operators - 667 man-hrs @ Vt 100/hr		66,700
(ii)	skilled labor - 30 man-hrs @ Vt 250/hr		7,500
	TOTAL gasifier labor costs	Vt	315,000

During normal Lister operations over two years, unskilled labor costs and skilled labor costs are estimated to total Vt 13,300 and Vt 15,000, respectively.

(h) forestry costs, including labor, fertilizers, insecticides, fencing, tractor hire and other miscellaneous items totalled Vt 350,000. Fuel preparation was done at no cost by students.

(i) the maintenance costs of the gasifier, including spare parts, were covered by the manufacturer under guarantee conditions. Therefore, no maintenance costs were incurred in the two years under review. However, this gasifier plant will require maintenance during its lifetime and the assumption is made that these costs will be higher than those incurred by the Lister diesel plant. A figure of Vt 338,000 is assumed for the base case. The Lister plant is estimated to have, on average, repairs and spare parts costing Vt 80,000.

(j) the lubricant costs of the gasifier amounted to Vt 120,000 while the Lister is estimated to consume engine oil to the value of Vt 60,000.

General Comments

Under the local conditions prevailing during the review period, electricity generated by the wood gasifier at 33 Vt/kwh was 30% more than that produced by the Lister diesel plant. Factors which contributed to the gasifier's higher specific power cost include the costs of labor, maintenance and lubricants. Forestry costs, part of the installation's total operating cost, is the most influential factor determining the cost of gasifier-generated electricity. Should it be unaccounted for, electricity from the gasifier system would be 27 Vt/kWh or 15% higher than that calculated for the Lister. Overall, the wood gasifier has proven to be more expensive to operate in spite of savings made on diesel fuel.

Sensitivity Analysis

Only one parameter was varied . ime while the values of the other factors were kept equal to base case assumptions. Power production and operating hours have been excluded from this analysis as the primary objective of the analysis is to observe the effects of input costs on specific power costs during the 23-month review period. The sensitivity analysis obviously shows the dominant effect of the gasifier's initial capital cost on the specific power cost if capital is taken into account. Besides initial capital cost, diesel and wood fuel costs are the major factors which influence the economic viability of the two energy systems. The specific power costs are not significantly affected by variations in the other input costs. Table 3 gives an overview of the outcome of calculations.

Table 1:

Operational Characteristics of Wood Gasifier and Liciter Diesel Set

Characteristic	Lister Diesel	Wood Gasifier
- installed capacity (kW)	25	25
- lifetime (yrs)	20	20
- initial investment (Vt)	0	0
- power production (kwh/yr)	29500	29500
- operating time (hrs//yr)	2582	2582
- fuel consumption & cost		
- diesel (l/yr)	11800	
- diesel cost (Vt/l)	50	
- wood (t/yr)		64.32
- wood cost (Vt/t)		8000
- labour cost (Vt/yr)		
unskilled	6927	34740
skilled	7813	3906
-labour total	14740	38646
- forestry works (Vt/yr)		
- total (incl. labor, fertilizer, seeds, fencing, tractor etc.)		182292
- maintenance and repair (Vt/yr)	41667	176042
- lubricants (Vt/yr)	31250	62500

Table 2

Comparative Economical Analysis of Wood Gasifier and Lister Diesel Set

Costs (Vt)	Lister Diesel	Wood Gasifier
- annualized capital cost	0	0
- annual operating cost		
- fuel	590000	514560
- labor	14740	38646
- forestry works		182292
- maintenance and repair	41667	176042
- lubricants	31250	62500
Total annual cost	677657	974040
Specific power cost (Vt/kWh)	22.97142	33.018305

Table 3

Results of Sensitivity Analysis

Variable	Value of variable	Lister Diesel	Wood Gasifier
BASE CASE		23 Vt/kWh	33 Vt/kWh
1. capital cost	12681314		84
(int. 10%)	3020000	55	
2. diesel cost	+ 50%	33	33
+	10%	25	33
-	10%	21	33
3. wood cost	+ 10%	23	35
-	10%	23	31
4. labour costs	+ 10%	23	33
-	10%	23	33
5. forestry costs	+ 10%	23	34
-	10%	23	32
6. maintenance &	+ 10%	23	34
repair costs	- 10%	23	32
7. lubricant cost	+ 10%	23	33
	- 10%	23	33

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CASE STUDY OF VILLAGE BIOMASS-STEAM POWER GENERATION PLANT UTILIZING WASTE HEAT FOR COPRA DRYING: NAVAKAWAU VILLAGE TAVEUNI FIJI

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Introduction

A wood-fired steam power generation plant producing electricity for village lighting and hot air for crop drying was installed in Navakawau village, on the Fijian island of Taveuni, in November 1987. This paper provides a description of the Navakawau system, examines its costs and potential benefits and reviews its operating history over the past three years. The review is based on two evaluation reports, the first undertaken by PEDP (1) approximately six months after commissioning of the steam plant and the second, undertaken by the University of the South Pacific (3) at the request of the Fiji Department of Energy (DOE), carried out nearly two and a half years after commissioning. Additional information was also made available through an internal DOE note (10) and discussions with staff of the DOE in Fiji.

The steam plant is reportedly used only intermittently and only for the purpose of copra drying. The possible reasons for the apparent failure of the project is the main focus of discussion in this paper. The paper also briefly considers the suitability of this technology for other rural applications in the Pacific in the light of experience gained from the Navakawau project.

Background

Navakawau village comprises a population of approximately 370 people in 47 households. The village is located on the southern end of Taveuni, at the end of the main road which links the main centers on Taveuni, and in an area which has historically been a high copra producing district. the village has a small health center and co-operative store but few other services. The main occupations within the village are subsistence agriculture and fishing with commercial production of copra, dalo and yaqona (kava). At the time of project inception (1984), the village also had an established and locally run co-operative which processed and marketed their produce.

Project Justification

Navakawau village was selected as a suitable site for a demonstration of a steam power cogeneration project on the basis of the following:

(a) the close proximity of the site to an existing and successful, commercially operated 30 kW capacity steam plant at Wainiyaku plantation, and the owner's willingness to providing technical support with both the design and operation of the steam plant;

(b) the village displayed the social cohesiveness necessary to implement and support the project;

(c) the village already had reasonable housing, water supply and access to school and health services;

(d) the village's displayed willingness to contribute to the project financially and through the donation of its labor for the establishment and running of the plant;

(e) a reported substantial, commercial production of copra (150 tonnes/year), yaqona (40 tonnes/year) and cocoa (20 tonnes/year) the value of which would be enhanced with the use of a high grade crop drying facility;

(f) the reported availability of quantities of coconut wastes and other supplementary woodfuel resources adequate to fuel the plant on a continuing basis;

(g) an established village co-operative infrastructure, which processed and marketed local produce and was assumed capable of managing the financial and labor resources necessary to successfully operate the plant;

(h) the proposed use of a mature technology which was relatively simple in concept and robust in design;

(i) an opportunity for the village to materially raise its living conditions through the provision of electric lighting;

(j) an established system for the transport of coconut wastes and other fuelwood to the plant site; and

(k) the willingness to donors to meet the capital costs of the plant.

Project Proposal

Project planning commenced in 1984. Following discussing with the owner of the plantation at nearby Wainiyaku and the Fiji Department of Energy, the people of Navakawau, in September 1984, made a request through the DOE for foreign aid assistance to cover the capital cost of the plant.

Justification for implementing the project, submitted to one of the principal financial supporters of the project was based on several grounds. The project would:

(a) provide an electricity supply, for a television receiver 1/ and sufficient lighting for children to do their homework at night;

(b) save cash spent on kerosene and benzine used for lighting could be achieved (not quantified);

1/ The introduction of television was an issue that was being discussed at a national level at that time.

(c) improve crop drying facilities allowing more energy efficient drying of a reported 150 tonnes of copra, 20 tonnes of cocoa and 40 tonnes of yaqona produced annually 2/ by the village and reduce the need to burn valuable natural timber resources; and

(d) eliminate the inefficient and dangerous kiln dryers then used by the village for crop drying.

Based on this proposal, the United States Agency for International Development (USAID) agreed to meet the capital cost of the generation plant, about US$26,000. Initially, it was expected that the villagers could raise sufficient funds to cover the cost of reticulation and lighting for the village, but it became evident that the amount required, about F$10,744, was beyond their resources. The South Pacific Bureau for Economic Cooperation (now the Forum Secretariat) was approached for funds to meet this cost. The Forum Secretariat agreed to provide the required amount for reticulation and lights for the village. The villagers agreed to provide F$4,708 to pay for the building housing the generating plant and for construction of the crop dryer. The capital budget is shown in Table 1.

The villagers contributed labor for the construction of the plant and reticulation and accommodation for visiting technicians. Several hours of assistance was donated by a local plantation owner.

The village raised F$3,000 through paid labor by the men and fund-raising sessions of yaqona drinking, where drinkers paid 10 cents per cup. It took the village two years to raise the money. The balance of the $4,000 agreed contribution remains outstanding. According to local authorities a drought, hurricanes and unusually heavy social obligations reduced the ability of the villagers to save during the two year period.

The capital costs of the project are shown in Table 1. The Fiji DOE called for tenders for the supply of the generation plant in 1984. There was a 24 month period from the date of placing the order with the successful tender (early 1985) to delivery in Fiji in 1987 due in part to management changes at the steam engine manufacturing company. There was a further delay of some six months caused by slow clearance of funds for reticulation through the Fiji government.

Table 1: Capital Costs of Plant 3/

Funding source	$
USAID (plant)	US$26,571
Forum Secretariat (reticulation	F$10,744
Village (building)	F$4,708
TOTAL	$US40,027

F$1.00 = US$0.87088

2/ Stated production of cash crops by the village was later found to be grossly overstated.

3/ Excludes the value of village labor.

Plant Design and System Specification

Specifications of the steam system installed at Navakawau are as follows:

Boiler - a vertical, single pass, firetube boiler made by Ray Burner, with a design pressure of 150 psig, fired by coconut husk and shell and wood;

Steam Engine - a Skinner steam engine (model E-5NL) 125 psig rated at 10 kW and coupled originally to a 10 kVA 3-phase alternator producing electricity at 240 V. The existing alternator is a Stamford (type PC164E) producing 3-phase electricity (240 volts per phase) and rated at 20kVA.

Condenser - a heat exchanger consisting of a large radiator, forced-air cooled, condenses the steam leaving the engine. A 2.25 kW motor drives the condenser cooling fan. Hot air is ducted to the crop drying bed with some returning to the boiler to enable forced draft firing.

Feedwater System - a rainwater tank attached to the fuel drying compartment collects water for the boiler. A 1.1 kW motor drives a boiler feedwater pump.

Powerhouse - the steam generation plant was installed and housed in a large open (two-sided) shed. The powerhouse also has fluorescent lighting and a power outlet.

Fuel Storage Shed - an open sided shed serves as a fuel storage area, measuring 6m x 4m floor area, and is situated adjacent to the boiler.

Plant Design Data

The original plant design was based on an assumption that the village produced in the order of 150 tonnes of copra annually, equivalent to an average of approximately 0.4 tonnes of copra per day.

It was estimated from published data (3) that 1.0 kg of dried copra would yield about 3 kg of air-dry husk and shell assuming 30% moisture content (percent of wet weight basis). No detailed estimation of this design parameter was made specifically for the Navakawau area however.

On this basis, available residues would amount to approximately 450 tonnes per year or 1.2 tonnes per day.

Biomass Resource Assessment

It should be noted at this point that there was no documented assessment of the existing village biomass resource or an evaluation of likely future fuel resources carried out prior to the acceptance of the project proposal by the funding agencies. This situation appears to have persisted until some three years after project implementation. Fuel availability appears to have been based on over-optimistic assumptions of annual copra production by the village and the subsequent quantities of coconut residues available as a result.

In 1990, a preliminary assessment of fuel availability was carried out (2). It indicated that 95 hectares of land under coconut was available to the village from which copra was produced.

It assumed the production of approximately 1400 kg of coconut residues per hectare per year (obtained from a previous study (8) from which a total of 130 tonnes of residues would be available annually to the village. This figure is in general agreement with reported annual copra production of 40-50 tonnes (see Table 2 below) for the village.

Copra sales figure quoted below 4/ were originally obtained from the Fiji Department of Co-operatives to which the village co-operative was affiliated and through which the village received a subsidy of $20 per tonne for export copra.

Table 2
Delaitabana Co-operative Society
(Navakawau Village, Taveuni)
Copra Sales 1979-1989

Year	Sales (tonnes)
1979-80	77.7
1980-84	not functioning
1984-85	62.9
1985-86	50.1
1986-87	40.9
1987-88	6.1
1988-89	10.1
Average(6 yr)	41.3

From the figures shown in the above table, there appears to be little justification for the annual copra production figure indicated in the original proposal (150 tonnes), a figure which was subsequently used in the detailed design of the steam plant. A figure of 40-60 tonnes would appear a more realistic estimate of copra production at the time of the project proposal.

Fuel Consumption

The specific fuel consumption (the amount of fuel required to product 1 kWh of electricity) was not measured directly during plant operation. An initial estimate was made however, based on the known fuel requirement of the Wainiyaku system which Feinstein (1984) records at 5.9 air dry kg of coconut fuel or wood per kWh of electrical output at the alternator. Specific fuel consumption of the Navakawau plant was originally assumed to be slightly higher and a figure of 5.0 air dried kgs of fuel per kWh produced was used in design calculations. On this basis, fuel consumption over an 8 hour shift, with full rated alternator output of 10kVA, would be about 400 kg of air dry husk/shell or wood. Added to this however is a requirement for approximately 100 kg of fuel for preheating and start-up of the plant, bringing the total fuel requirement to proximately 500 kg per 8 hour shift.

4/ Reproduced from reference 2.

Manufacturer's specifications for the steam engine indicate however, that specific steam consumption (the amount of steam required per kWh of output from the alternator) for a 30 kW rated machine amounts to 55.7lbs/hr whereas 64.2lbs/hr of steam is required for each kWh produced by a 10kW rated unit. The steam utilization efficiency of the 10 kW plant is therefore 87% (55.7 lbs per hour / 64.2lbs per hour) as efficient as the larger 30 kW machine. A revised figure for specific fuel consumption for the 10 kW unit is therefore calculated at 6.8 air dry kg per kWh produced (i.e. 5.9 kg per $k/Wh_{30kW\,plant}$/.87). It should be noted that this figure assumes that the thermal efficiency of the boilers producing the steam to run the engines is the same.

Using the revised design figure of 50 tonnes of copra produced per year and, again, assuming 350 work days per year, the yield of air dry husk and shell is estimated at about 0.4 tonnes per day (50 tonnes copra per year / 350 days x 3 kg residues per kg copra = 0.4 tonnes fuel per day).

Supplementary Fuel Use

It is not realistic to expect that this quantity of coconut residues would be available each day. Copra production is seasonal and is therefore likely that coconut residues would need to be supplemented with wood during periods of low copra production particularly if fuel storage area is limited.

The village found necessary to supplement available coconut fuel with wood to improve heat production in the furnace. In addition, on some evenings the plant was operated solely to provide electric power to the village. As no copra was dried on these occasions, and therefore no residues available for fuel, supplementary wood fuel requirement increased. It was reported (1) that coconut residues for the Wainiyaku system were also supplemented with wood, despite the use of a proportionally larger drying area and a drying hopper to dry the coconut husks using surplus heat from the plant.

On the basis of 400 kg of fuel per day and a specific fuel consumption of 6.8 air dry kg per kWh, the maximum period of plant operation, taking into account start-up fuel requirement of 100 kg, would be approximately:

$$300 \text{ kg fuel per day} / 6.8 \text{ per kWh} / 10 \text{ kW}_{rated}$$

$$= 4.4 \text{ hours per day.}$$

Fuel Transport

The transporting method for coconuts remained unchanged following installation of the steam plant with whole nuts being conveyed from distances of up to 2.5 km to the plant site for splitting. Horses were the usual method of conveyance, with each household having access to at least one horse, followed by hand carrying in sacks and occasionally the use of two private vehicles which were available for hire.

Fuel Storage

The boiler was designed to burn coconut residues (husk with shell attached). When freshly cut, the fuel was too wet to burn in the boiler and required a drying period of at least one week, depending on weather conditions. Fuel was therefore stored under cover in an open sided shed adjacent to the boiler.

Six months after commissioning, it was recommended[1] however, that for thorough drying of fuel, particularly in rainy weather, a larger covered drying area was required at Navakawau.

Installation and Commissioning

Plant installation was carried out under the supervision of a local plantation owner in late 1987. The plant was commissioned and commenced operation in November 1987. There were minor routine adjustments made in the first few weeks after commissioning to the steam engine bearings as they "settled in". It was necessary also to clean filters several times because corrosion had occurred in the condenser and piping owing to the long period in transit and prior to installation. Technical assistance was provided to the village by a local plantation owner in carrying out these tasks. The plant was then turned over the village.

Plant Operation

Four operators, after two weeks of training at Wainiyaku, ran the plant. Each took turns in being solely responsible for an evening's shift and were paid, from co-operative funds, an amount based on the amount of copra dried or $4-5 per shift at full production level.

Plant Maintenance

Funds necessary for this purpose were collected through a levy of $20 per tonne of copra produced. These funds were reportedly (1) managed by the co-operative and were used solely for this purpose.

It was originally anticipated that, with a production level of 150 tonnes of copra per year, the levy would yield $3,000 and was considered (1) adequate to finance necessary recurrent expenses (hydrazine, boiler feedwater chemicals, engine lubricating oil) with minor repairs and maintenance. At a production level of only 50 tonnes per year however, copra drying would gross only $1,000.

Spare parts could be purchased through the South Pacific agent for the boiler and steam engine manufacturer, who was resident on Taveuni. Technical assistance was also reportedly available from this source.

Routine Maintenance Procedures

As shown in Table 3 below, routine plant maintenance procedures were not complex. It was assumed that routine maintenance could be carried out by an operator after a short period of training with the exception of an annual boiler safety inspection, required under industry legislation, and carried out by a government appointment inspector.

Table 3
Routine Maintenance Schedule

	Frequency	Downtime	Description
1.	Daily		Check boiler feedwater levels
2.	Daily		Check boiler feedwater chemical levels
3.	Daily		Check engine cylinder lubricator oil levels
4.	Weekly	2 hours	Clean boiler tubes with brush and clean as from under firebox grate
5.	6 months	1 hour	Adjust/tighten engine crosshead bolts
6.	6 months	1 hour	Change engine crankcase bolts
7.	Yearly	3 hours	Change steam packing
8.	Yearly	2 hours	Boiler safety inspection (carried out by a government inspector)

Operating Procedures

The boiler was lit about 0.5 hours before electric power is required. When sufficient pressure is built up the engine-alternator was started and provided electric power for the fans and pumps, providing preheated air under forced draft to the boiler furnace. When full heating rate was reached, the three single-phase spurs to the village were switched in. If steam production was insufficient to provide power to all three spurs, one or two could be switched out. A degree of loading imbalance could be tolerated by the alternator without damage, as the operation of the three phase motor driving the condenser fan provided sufficient loading for the phase or phases not carrying the village lighting load.

A batch of up to 1.5 tonnes of copra could be fully dried over a 16 hour period. It was anticipated that the plant would be operated for 4-5 hours, 7 days per week and that daily running time could be increased to 8 hours or more when a large batch of copra was being dried.

Electricity Requirements and Usage

Design electrical power output of the steam plant was 10 kW. Power distribution to the plant and for village domestic needs is summarized in Table 4.

Powerhouse

Electric power is required to operate a 2.5 kW, 3-phase motor driving the condenser/crop-dryer fan with a smaller (1.1 kW) single phase motor being run intermittently to drive a feedwater pump.

Village Lighting

All 47 houses in use when the project was implemented received electricity. Each phase of the alternator's output provided single-phase power to one third of the houses. Reticulation of 240 volts was via underground cables. All electrified houses had their own fuse box and three ceiling-mounted, individually switchable, high efficiency 36 watt lights. A number of houses subsequently [illegible]ed additional 36 watt (44 watt including ballast load) fluorescent tube light fittings at the[illegible] expense. There was lighting and a power outlet installed in the village hall and at least one household used an electric iron there. One householder used one of the ceiling light sockets to power a radio through a bayonet fitting.

There was no regular collection of fees from households for their electricity consumption. The villagers considered that many households would find it difficult to have the cash available on a regular collection date. They felt that collection through a levy on copra was a much better way of securing funds for repairs and maintenance.

Table 4
Power Distribution

Design power output from steam engine	10.0 kW_{mech}
Available power (93% alternator efficiency)	9.3 kW_{elec}
Power for ancillaries (feedwater pump, lighting, etc).	-1.4
Power available at switchboard	7.9 kW
Overall distribution losses (assume 10%)	-0.79 kW
Power to heat exchanger blower	-2.25 kW
Net available power to village	4.86 kW
Domestic power requirements (47 houses at 100 W/house)	4.70 kW

Anticipated Project Income and Expenditure

Estimated income and expenditure accruing directly to the operation of the steam plant are discussed below and summarized in Table 5.

Improved Copra Quality

Financial benefits would accrue to the village with an improvement in copra quality. Based on present prices, the differential paid in Fiji for the higher grade of air dried copra is $F20-30 per tonne. This increase would apply for at least half (25 tonnes) of the annual copra crop, formerly smoke dried in drum dryers. In addition, wastage (rotting in storage, loss of drying batches due to fire) could be eliminated. Losses are assumed at 5% of total production at a cost of $250 per tonne. Based on an annual copra production of 50 tonnes, the increase in village revenue is estimated at $1,250 per year.

Savings in Kerosene and Battery Purchases

Reduced expenditure on kerosene and flash light batteries brought about by electric lighting was expected to be a substantial cost saving for the village. Savings were estimated from surveys carried out in rural areas of Fiji (9). Though it is common in Fiji for households to use both kerosene and benzine, kerosene lighting only is considered. Kerosene consumption for lighting averages 5.3 liters per household per month for the total surveyed population in five areas. Most of this would be displaced if the plant were operated 350 days per year. Kerosene savings should therefore be of the order of 3,150 liters per year for the 47 electrified households. At the bulk (20 litre drum) price of F$0.63 per litre in Taveuni (1988) savings were estimated at F$1,980 per year for the entire village. As some of the kerosene is bought at trade stores in smaller quantities at higher unit prices, the cash saving to the village may be higher.

There would be additional savings in reduced replacement of lamps and lamp parts, although households would need to retain lamps for evenings when the plant is not working and late-night use after it shuts down. Savings are therefore not estimated.

Flash lights were still necessary for outside use, so the reduction in battery use resulting from better indoor lighting would be small. However, even a saving of two batteries per household per month corresponds to an annual cost saving for the village of about $700.

Total economic benefit to the village brought about through cost savings on kerosene, lamps and lamp parts, and torch batteries, may be of the order of $F2,500 per year.

It should be noted however, that as electricity supply was provided at no charge to the households, there was no mechanism to transfer these savings to financing the running costs of the steam plant. Therefore from the point of view of the plant operation, these savings could not be utilized and were not credited to the project.

Elimination of Drum Dryers

The drum dryers previously used to dry crops required repairs and regular replacement as the drums burned out and dryers were occasionally destroyed by fire. The average cost involved is not known, but to dry 50 or more tonnes of copra a year, it was assumed(1) to be at least several hundred dollars per year. It was not clear however, whether any of these savings were creditable to the plant in payment for the service provided.

Net Increase in Wages for Crop Drying/Plant Operation

The wages of the firemen were a cost to the co-operative, but they were retained within the village, so they are a transfer payment rather than a true cost to the village. These wages might total F$1560 (52 weeks x F$30) in a full year. Previously, labor was employed to operate the co-operative's drum dryers, so the estimated net increase in costs to the co-operative is less than this figure. For the purpose of estimation, $1500 is assumed.

Net increase in Use of Chainsaw to Cut Firewood

The use of a chainsaw to cut supplementary fuel for the boiler was a cost directly attributable to the operation of the plant. It was estimated that the average requirement was perhaps 50-100 kg of firewood per day. Petrol expense was therefore not expected to be high. Chainsaw breakdowns however, could be expensive. A figure of F$500 per year to cover the cost of spares and necessary replacements was considered realistic. However, it may be noted that to maintain copra production with drum dryers, firewood harvesting was needed to supplement husk and shell supplies in wet weather, so the net increase in chainsaw operating cost brought about by the new system are probably below F$500 per year. For the purpose of cost estimation, a figure of $500 is assumed.

Cost of Electric Lamp Replacement

Electric lamps would have to be replaced as they burn out. Annual operating duty was estimated at around 1200 hours, assuming lamp use for 4 hours per night. The type of lamp used has an operating life of about 2000 hours and a wholesale price of F$2.00. Assuming lamps are purchased through the co-operative at the wholesale price, annual cost for the entire village was estimated in the region of F$200.

From Table 5, it is apparent that the project would likely face a significant cash shortfall with expected annual expenditure on plant running costs approximately three times that of expected income. This problem was obviously exacerbated as copra production declined (see Table 1) and with the project's sole income.

Table 5
Summary of Project Financial Income and Expenditure

Annual Income	Value (F$)
Revenue from copra dried @ $20/tonne	1,250
Estimated Total Annual Income	1,250
Annual Costs	
Feedwater treatment, lube oil, sundry spares and materials	150
Plant maintenance and overhaul major replacements, etc.	1000
Net increase in labor costs	1500
Chainsaw associated costs (fuel, spares, replacement, etc.)	500
Replacement of lights, fittings	200
Boiler inspection	200
Estimated Total Annual Costs	3550

Project Status - June 1988

The project evaluation was carried out by PEDP in June 1988[1]. The major findings are summarized below.

Plant Utilization

During the few weeks prior to the visit, the plant had only been operated 3.4 nights per week because of a shortage of fuel. This was reportedly caused partly by a recent drought and two hurricanes which have greatly reduced coconut yields in the area. the annual yield of a local plantation had been reduced from 400 to 120 tonnes. Anoth‹r cause of shortage was the sale of much of the recent yield of coconuts, in the form of whole r o the Fiji Army. The unusually wet weather had also reduced the effective fuel supply by c asing the degree of fuel drying.

The report assessed that, provided there was sufficient fuel, the operating hours could be extended. It was also apparent that the electrical power output was close to the design maximum obtainable from the boiler with the existing fuel quality (see above).

Plant Maintenance and Reported Mechanical Failures

There were no reported mechanical problems with the plant since commissioning. The equipment was reportedly in as-new condition.

Perceived Social Benefits

All the villagers interviewed were reportedly very proud of the plant and considered that it brought substantial benefits to the village, none of the villagers were opposed to their project. The availability of household lighting was more highly valued than the improvement in crop drying.

Expansion plans were discussed with a number of householders, who indicated that appliances (radios, refrigerators, etc.) were desired by at least some. There was however, little scope for electrical appliance use by the households during the evening when lights were in use. With a maximum operating period of only 4-5 hours per day, it is unlikely that the plant would have been operated during the day in order to support such loads specifically and the expense of lighting.

Project Status - April 1990

A seco project evaluation was undertaken by USP in April 1990. The findings are summarized below:

Plant Utilization

The plant was not operational and had not been used for over one month prior to the visit.

Crop Production and Drying

Copra production from 1987 (see Table 1) had been severely reduced due primarily to a drop in export market prices and the reluctance of the co-operative to purchase village copra. Cocoa production was nonexistent. Yaqona had become the principal cash crop for the village and attracted considerably higher prices than copra. Dalo was also a major contributor to the village's income and also attracted a significantly higher price than copra. There was therefore a limited requirement for the drying facility. For that produce requiring drying, the village hnd reverted back to the original durum type dryers.

Fuel Supply

With reduction in copra production, a convenient fuel supply for the steam plant was reduced considerably. Wood, with a considerably higher value to the village than coconut residues, therefore necessarily became the principal fuel. Wood was available from village-owned land though at some distance from the village. Transport of fuel also appeared to be a major problem with motorized transport, available at $25 per trip, being required to transport sufficient wood to run the plant.

The supply of fuel was only possible at the expense of labor, chainsaw fuel and maintenance with no means of financial compensation for those engaged in this task. It was also apparent that much of the wood was being cut using hand tools (axes and cane knives).

Fuel Storage

A larger fuel drying and storage area was identified by the village as a high priority in order to reduce the requirement for supplementary firewood and associated chainsaw use and expense. There appeared little justification for this proposal however, taking into account the small amount of copra produced by the village at the time.

Plant Maintenance and Reported Mechanical Failures

As copra production fell, operators of the plant received less in remuneration for their hours of attendance at the plant. They lost incentive to both operate and maintain the plant. It was reported (2)(10) that the plant was in need of general repairs and maintenance. Unlagged heat pipes, broken gauges and valve taps were reported. The plant showed general signs of neglect.

Plant Management Structure

There appeared to be problems with the organization of fuel collection, plant operation and finances. After commissioning, a committee had been established, comprising those who had been trained at the Wainiyaku plant. Though this arrangement appeared to be successful, following recommendations of the Turaga-in-Koro, the village co-operative assumed control. After two weeks however, the cooperative declared the plant to be financially non-viable and the Turaga-in-Koro re-assumed responsibility.

Other Village Priorities

It was reported that the village water supply system was in need of repairs and that school bus services became problematical both of which required some financial input from village resources.

Reasons for Failure

A summary of factors contributing to the failure of the project is listed below:

(a) a poor or incomplete initial project design which used unsubstantiated estimates for key design parameters;

(b) financial non-viability;

(c) incentive for copra production fell as export prices decline while yaqona became a more financially attractive crop both in terms of prices paid and ease of production;

(e) plant redundancy brought by curtailment of copra production in favor of other more financially attractive cash crops;

(f) insufficient readily accessible fuel supply which worsened as copra production declined;

(g) no means of transferring the savings in household kerosene, battery etc. consumption to finance plant running costs;

(h) reduced copra production which lead to a reduction in cash available to meet plant maintenance and operating costs;

(i) as operators' wages were based directly on copra production, as production fell, operations' incomes and incentives to work on the plant also declined;

(j) little financial incentive for individual copra producers to utilize the drying facility with the price margin paid for improved copra quality close to that of the cost of drying;

(k) no mechanism for the provision of fair compensation to village members who provided the required additional fuel for the plant;

(l) insufficient electricity output necessary to support additional household appliances;

(m) a management structure which arguably lacked responsiveness and flexibility in decision making, entrepreneurial skills and incentive to develop alternatives for revenue generation as the copra market declined;

(n) other priorities (village water supply and school bus services) became more important for the use of village finances;

(o) **the apparent perception of the village that, under the circumstance, kerosene lighting was a better option than to persist with the generation of electricity.**

Analysis and Implications for Other Rural Electrification Projects

Technology Choice

It remains demonstrable that the technology works, at least in a commercial environment prevailing on a plantation nearby to the village. It has not been established, on the basis of the evaluation reports, that the technology was itself as main contributing factor in the project's failure. There were several other factors associated with this project which masked a pragmatic appraisal within the village environment.

The 10 kW steam engine is the smallest commercially available engine 5/ and the analysis of fuel requirements indicates that at least 50 tonnes of copra per year must be dried to produced sufficient husk and shell to operate the plant daily. From experience with operating plants 6/, there is a need to supplement the supply of husk and shell with woodfuel.

Established agro-processing businesses appear be likely first targets for the introduction of steam power generation technology into other countries. However, such business should also consider the other biomass-fuelled heating technologies described by Gilmour.

Aid Agencies Contributions

Most of the capital cost of the project was provided through donors. However, it was clear that finances were made available on little justification of either project design or future project potential. It may be argued that the village contribution to the projected was small in comparison to its overall costs. Under the circumstances however, this was fortunate in that the financial loss incurred by the village as a result of the project's failure was minimized.

Project Design

Plant sizing was based on unsubstantiated estimated of fuel resource availability and a lack of appreciation of likely future supply availability based on a declining copra market and conditions existing in other feasible cash crop alternatives.

Within a short period after commissioning of the plant, production of copra declined and was eventually replaced by other crops (yaqona and dalo) as the principal cash income for the village. Accompanying this decline, accessible fuel supply became unavailable and in fact that need for the drying facility became redundant. The cash returns ascribable to the plant from copra production disappeared. The financial gains from other crops were not transferred to support the project. There appeared no incentive to maintain the plant even for the provision of electricity for village lighting. Its limited output precluded the use of other appliances and lighting could, apparently quite adequately, be provided using other energy sources (kerosene).

5/ Reportedly no longer manufactured although similar plants may be available from Brazil.

6/ Wainiyaku plantation

Financial Viability

The project, though initially appearing to provide overall benefits to the village, did not have financial viability from its inception. Though benefits accrued to the village as a whole, principally through the displacement of other energy commodities, the mechanism did not exist to transfer these savings to the running of the plant. The village became the recipient of free electric lighting. These transfers were vital to the financing of project running costs. Revenue for a levy on copra dried, essentially the only direct income from the plant operation, was based on a three-fold over-estimation of copra production. As copra production fell, so did income and with it the ability to finance operating costs.

Copra drying charges were set such that there was little incentive for individual copra producers to make use of the plant. This would have severely limited the potential to attract outside producers to make use of the plant, particularly if transport costs were also a consideration.

Characteristics of the Village

The village was perhaps not as socially cohesive as first thought though the villagers were able to work together on establishing the project without major disruptions. They were prepared to make an initial commitment of funds and labor. The village had reasonable housing, a water supply and access to school and health services though the quality of at least some of these services declined and subsequently needed financial input from village resources. There were reportedly divisions within the village over major issues which obviously effected village organization and decision making ability. However, these aspects are not controllable from the point of view of designing a successful project.

Infrastructure

Support services necessary to install and maintain the plant (road, port, regular shipping and airline services, mechanical workshop (at Wainiyaku), good communication with the agent for the technology) was in place at the time of the original proposal. The village relationship with the agent however, appeared to decline over time with apparently less support being forthcoming as a result.

Plant Management

Management changed shortly after project commissioning. Though disorganization within the management structure would have been a key fact in the apparent abandonment of the project by the village, it may be argued that the project had little chance of success simply from a financial point of view and that the plant was abandoned simply for normal commercial reasons. the plant became redundant.

Prospects for Cogeneration in Rural Electrification Programmes in the Pacific Islands

It would be difficult to introduce steam power generation technology directly at a village level in other Pacific island countries without first gaining in-country experience and an assessment of available technical support. As steam technology has only been utilized by one or two countries within the region, mainly in support of commercial agro-businesses (sugar cane), it would be very doubtful if appropriate technical support would exist in other countries. If steam power generation could be introduced at an agro-processing facility so that in-country experience and support was developed, the introduction of village level steam power generation/electrification projects could be considered. However, there may be few Pacific island villages with the characteristics necessary for success.

Particular caution is also required when considering the introduction of steam power generation in atoll locations where agricultural scientists advise that coconut husks should be left around the plantations so that organic matter and nutrients, particularly potassium, are returned to the interfile atoll soils as the husks rot down (6). It might be possible to fuel a steam power generation system with coconut plantations on an atoll though detailed resources and environmental assessment would be essential.

VIII. TECHNOLOGIES FOR HOUSEHOLD ELECTRIC POWER: LIGHTING AND APPLIANCE

CASE STUDY:
HOUSEHOLD ENERGY CONSERVATION: LIGHTING IN FIJI

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Introduction

There are numerous examples of recent sophisticated analyses showing that it is worthwhile for a government to encourage energy-efficient domestic appliance (lighting, refrigeration, videos, etc.) whether this is considered from the perspective of the consumer, the power utility or the nation 1/. It is often cheaper to conserve energy than to pay for new capacity. In the case of the small Pacific Island countries, government energy officers seldom have the time, the information, or the analytical tools to assess these options. This paper looks at the possible impact of widescale use of compact fluorescent lights in fiji households based on information readily at hand, a time limitation of one working day including interruptions, no typist or other help available, calculations with a simple calculator and common sense. This sort of approach will not provide definitive answers but can usually tell you whether its worth investing resources to carry out a more detailed analysis. 2/

Electrification within Fiji's Households

Fiji has about 125,000 households whom nearly half 3/ have access to electricity. Of electrified urban households, 99% were connected to the Fiji Electricity Authority grid. Of rural electrified households, 73% were FEA and most of the rest had stand-alone diesels.

1/ Slightly revised following comments from Graham Birse and James Goodman, both of the Fiji Department of Energy, on a draft of 14 October 1990.

2/ For example "Improving Appliance Efficiency in Indonesia" (Schipper, L & Meyers, S., Oct 1989) and " Conservation Potential of Compact Fluorescent Lamps in India and Brazil" (Gadgil, A. & Jannuzzi G., July 1989) both from the Energy Analysis Program of Berkeley Lawrence Laboratories, California. Both are available from PEDP.

3/ This is estimated (and rounded off) from undated notes on energy use in Fiji provided to a May 1990 workshop in Tahiti on photovoltaics and rural electrification. Data appear to be those of 1987.

Table 1. Electrification in Fiji

	Total	Urban	Rural
Households	125,000	50,000	75,000
Electrified	48%	75%	30%
Non-electrified	52%	25%	70%

Two detailed surveys of household urban/peri-urban energy use were carried out in Fiji in 1987/1982 4/:

Table 2: Urban Surveys of Electrification in Fiji

Survey	Households Surveyed			Year	Consumption
	Total	Elec	%Elec	Surveyed	kWh/m/Elec hh
Greater Suva	1312	1011	77%	1981	153
Nadi-Lautoka	826	727	88%	1982	103

The pattern of electricity use is shown below and in Figure 1 as a percentage of total household consumption with Brazil (1987 5/) for comparison:

Table 3: Urban Electricity Use (Percentage)

Survey	Fridge	Lights Fl	Lights Inc	Cooking	Water heating	Video	Laundry	A/C	Iron	Misc	Total
Suva	45	10	5	12	12	3	3	2	2	6	100
Lautoka	53	- 10 -		7	9	?	2	7	5	7	100
Brazil	39	10	?	?	25	6	1	10	2	7	100

In all cases, household refrigeration is surprisingly high and an obvious area for long term conservation: both the Suva and Nadi-Lautoka surveys included appliance sampling which indicated that, on average, household refrigerators used nearly 800 kWh/ year. The best European and Japanese single door models (Figure 2) use only 180 - 300 kWh per year. For small countries with very few sources of imported refrigerators (mainly inefficient New Zealand models?), it would be worthwhile to consider policies to encourage high efficiency refrigerators even if they are more costly. Compared to pre-1973, the efficiency of most appliances sold in Western countries (Figure

4/ "Urban Energy in Fiji: A survey of Suva's Household, Industrial and Commercial Sectors" (S. Siwatibau, 1987), and "Household Energy Use in Fiji: Report of the Nadi-Lautoka Domestic Energy Survey" (Lloyd, Kumar & Metham, 1982).

5/ From reference 1. The information on recent appliance efficiency is from the same source.

3) has increased significantly: refrigerators require about 40% less electricity per litre of capacity, washing machines 40% less, air conditioners 25% less per unit of cooling capacity, and even color TV sets 50% less for the same screen size.

Household Refrigeration

Household appliances are typically kept for 10 - 15 years so a change in the efficiency of newly-imported appliances would take many years to affect overall household electricity consumption. Household refrigerators use so much electricity, however, that it would be worthwhile to estimate the effect of a policy which restricted imports of all new household refrigerators to highly-efficient models. Using reasonable assumptions 6/, it appears that each consumer would save about US$0.3 million electricity bills during the first year growing to US$3.3 million after ten years. This is an extremely rough estimate but it does indicate that a more comprehensive analysis may be worthwhile.

Urban Household Light

Light globes or bulbs are replaced frequently and the relative efficiencies and costs for different types are known so a more accurate evaluation can be made for household lighting. An incandescent globe lasts for about 1,000 hours (750 hours if there are frequent power spikes). In Suva, incandescent lights are typically used 3.3 hours/day which is a 10 month lifetime assuming "clean" power. Although about 37% of electricity for domestic lighting in Suva is fluorescent, these are compact fluorescent (Figure 5) fit into a standard incandescent fitting and are both long-lasting and highly efficient; a 16 watt SL-13 7/ provides as much light as a 60 - 75 watt incandescent light and lasts about 10,000 hours.

Using simple techniques (See Annex 1), it can be shown that a household in Suva which replaces a 60 watt incandescent light used 3 hours per day with an SL-13, saves about F$30 (US$21) over the lifetime of the fluorescent light:

Table 4: Present Value Cost of Electric Lighting

	Fluorescent	Incandescent
Light type	SL-13	60 watt
Purchase Price	US$25.55	US$1.06
Present Value 8/	US$40.17	US$61.55

6/ A new 300 litre refrigerator in Fiji costs about US$700, electricity consumption is assumed to be 650 kWh/yr, and lifetime is 15 years. An energy-efficient model is assumed to cost 30% more and use 250 kWh/yr. Using the techniques of Annex 2, the discounted cost of the typical fridge is US$1,441; for the efficient fridge US$1,194. Fiji import statistics have not been published since 1987, an atypical year, so earlier imports of 5,000 per year were assumed growing at 2% annually saving 2 million kWh during the first year increasing to 22 million after ten years.

7/ The lamp itself consumes 13 watts and the electronic ballast, etc 3 watts.

8/ Present value of costs evaluated at a 10% discount rate over 10 years.

The actual savings (Figure 6) would probably be greater since the fluorescent lights would typically be used for lighting of more than 3 hours per day for sitting room use or night security.

Using the above estimates, if Fiji's 50,000 urban households each replaced 3 x 60 watt lights with compact fluorescent, the annual electricity savings would be 6.6 million kWh 9/ or US$ 1 million. The total present value of the savings to the consumers would be nearly US$ 3.5 million.

Value of Fluorescent Lighting to the Utility and the Nation

Assessing the value of compact fluorescent to the utility and the nation is more complicated. For the utility, the benefit is the avoided expenditure on new capacity (lower demand means purchase of new equipment can be delayed) minus the loss of revenue due to lower sales. This is complicated calculation for Fiji and could not be done with the information readily available. For example, a simple estimate 10/ indicates that 5.1 MW (8% of FEA's peak demand) would be saved if all of FEA's domestic consumers replaced 3 x 60 watt globes with SL-13 fluorescent. However, unlike most Pacific utilities, FEA's peak demand (Figure 7) does not coincide with the peak lighting load so this overstates savings. For most Pacific Island countries (diesel power, a peak demand which coincides with the peak evening lighting demand, and subsidized supply to consumers; see Figure 8), the savings to utilities would be appreciably higher than to the individual consumer.

Calculation from a national perspective would be similar to that for the utility except for the removal of all subsidies (these are internal costs within the economy). It would also be necessary to add any costs required to encourage or enforce use of the fluorescent.

Rural Household Energy Use in Fiji

Suliana Siwatibau carried out a number of rural household energy surveys between 1978 and 1982 11/. These are dated but still useful despite the widespread introduction of video systems since the surveys took place. A survey of electricity use within the Public Work Department's rural electrification systems is underway now but data are not year available. 1983. results from five communities are summarized below:

9/ (60-16w) (1,000 hrs) (1kW/1,000w) (3) (50,000) = 6.6 million kWh. Accounting for FEA's average losses of 11%, the electricity saved is 7.4 million kWh. One kWh costs the consumer US$0.149.

10/ (3 lights) (60-16w) (1kW/1000w) (51,000 FEA consumers) (67%) (1.0/.89) (1MW/1000kW) = 5.1 MW. This assumes a coincidence factor of 67% for evening lighting which may be high and 11% system losses which is about the FEA average.

11/ "A survey of Domestic Rural Energy Use and Potential in Fiji" (S. Siwatibau, 1978) and "A Survey of Five Rural Area of Fiji" (S. Siwatibau, 1984).

Table 5: Rural Household Energy Surveys in Fiji

Location	hh	% elec	kWh/ month	------ % using electricity for purpose---- lights	fridge	iron	radio	cooking
Somosomo	49	31	60	100	40	50	67	na
Baulevu	50	60	67	100	56	81	70	3
Ovalau	57	63	166	100	58	94	58	17
Sigatoka	51	31	73	100	50	69	68	12
Queen's Rd	48	56	100	100	82	100	85	11
Total	255	48	93	100	41	79	70	9

Notes:

1. kWh/month is for electrified households, not average of all households; kWh consumption was estimated from survey data.

2. Totals are averages; not weighted since the sample sizes are almost all the same and data not used for further calculations.

The above sample has a much higher rate of electrification (nearly 50%) than the national rural average shown in Table 1 (30%) and is not typical of rural Fiji. However, it does show that by 1983 electrical refrigerators were widespread in rural as well as urban areas. The earlier (1978) study assessed a number of PWD electrification projects in rural communities. Overall, 91% of all installed lighting in 50 communities was incandescent. The typical load was only 30 kWh/household per month which indicates that lighting was the dominant use 12/. This would seem to indicate that rural schemes are very highly subsidized with the community paying only a small percentage of the true initial cost and little more than the fuel cost thereafter. There is no incentive for them to buy expensive SL-13 lights. However, if PWD installed compact fluorescent when the systems were commissioned, there may be net savings to PWD if the increased cost of lights is offset by the lower initial cost of a smaller generating set. If this were the case, and the gensets were still operating at an acceptable load, the monthly fuel costs for the rural community would drop substantially.

The current PWD costs were not available as this was being written; however, a rough calculation for a community of 50 buildings 13/ using a 15 kVA genset indicates that this could be replaced with a 10kVA set. The added cost of the lights 14/ would be about US$1,230. If the smaller generator is at least $1,230 cheaper, the PWD could save money by buying compact

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12/ Assuming 8% losses, (2 lights (60w) (30 days/m) (1kW/1,000w) (5 hours/day) (1.0/.92) = 20 kWh/month. Losses are included because the total fuel costs is often shared among the households.

13/ 48 homes with 2 x 60w lights each plus a shop and church with lights each. Assuming an 80% coincidence factor in lighting use and 8% losses, the savings would be (104 lights) (60-16w) (1kW/1000)(80%)(1.0/.92) = 4 kW. Therefore, genset could be reduced from 15kVA to 10kVa.

14/ The import duty on fluorescent and incandescent lights is 32.5%. Assume duty-free ball at US$12.50 (SL-13) compared to US$0.65 for the 60w. The added cost is 104 ($12.5 - 0.65) = $1,232.

fluorescent. The community's fuel cost would drop by about US$179 per month 15/ or US$3.70/household/month, a significant amount for a rural family. Of course, provision would have to made for replacing the compact fluorescent as they burn out (perhaps with part of the monthly fuel savings) or consumers would substitute cheap incandescent lights and overload the system. An alternative would be the installation of small tube-type fluorescent if these were readily available in village shops for replacement later.

Policy Considerations

Despite clear life-cycle savings to the consumer, most people will not spend F$35 for an efficient light when they can purchase an ordinary light for F$1,45 or even less. The average person cannot afford the initial high purchase price and, in effect, uses a much higher "discount rate" than the 10% assumed in this example 16/. If calculations show that a programme of encouraging compact fluorescent is also beneficial from the utility and national perspectives, what policies will bring about the desired change? Some considerations follow:

(a) Calculations may show that it is cheaper to subsidize the lights (so people can afford them) than to install new generating capacity. Some utilities in North America save money by distributing compact fluorescent at less than their purchase cost.

(b) Where electricity is itself subsidized (sold at less than cost as in many Pacific Island countries), it may pay the government to shift some of this subsidy from the power utility to lights for consumers.

(c) Governments could consider raising the import duty on incandescent lights and lowering it on compact fluorescent, although the price difference between them is so high that the impact would be small.

Conclusions

The conclusion is that a few hours effort looking at the likely impact of a particular conservation possibility is well worthwhile. At least it can eliminate some prospects immediately and allow the energy planner (or his/her advisors) to concentrate more effort on those which appear from rough calculations to be worthwhile. Even to do this, however, some basic information is needed on appliances, their patterns of use, the value of the fuel saved, etc.

It might be a useful exercise to recalculate the examples of this case study using more recent information. Up-to-date surveys are usually the most accurate; as this example shows, though, even ten year old data can be useful. Where there are no data for your country, information from similar environments elsewhere in the region can be used for initial estimates.

15/ At assumed rural fuel cost of US$0.60/litre and consumption of 0.4 1/kWh, savings are (44w) (1kW/1000W) (104) (5 hours/day)(30 days/m) ($.6/1)(0.51/kWh)(1.0/.92) = US$179. The high fuel use per kWh is for poorly maintained equipment.

16/ Economists who study this sort of thing have calculated 35% as typical of low income people in both developed and developing countries.

Annex 1:

Relative Cost of Fluorescent & Incandescent Lighting

There are numerous methods of calculating the life cycle cost of an appliance, that is the cost of purchasing and operating it over its expected life span. These are based on the concept of the "time value of money", a dollar in hand today is worth more than a dollar expected in five years' time. The present worth of money spent (or received) in the future is calculated by discounting or translating future values to present values. $100 invested at 10% annual interest for six years has a future value (in six years) of $100 x (1.100) = $177.16. In other words, $177 in six years has a value today (present worth) or $100. By recording expected future expenditures 17/ of several alternative lighting methods, and discounting all costs to their present value, it is easy to compare the relative costs. PEDP has provided several books to national energy offices with examples for energy projects.

For lighting in Suva, we use the following assumption which favor the incandescent light for three reasons: a) the SL-13 probably provides the same light as a 75 watt bulb; b) the incandescent may have a lower lifetime than 100 hours; and c) some tests have shown up to 14,000 hours lifetime for SL-13 lamps. The net benefit of the fluorescent, therefore, may be understated.

Light type	fluorescent	incandescent
Price in US$	SL-13	60 watt
Lifetime	25.55	1.06
Annual use	10,000 hours	1,000 hours
Replace light	10 years	1,000 hours
Annual electricity	US$2.38	US$8.94

Notes:

1) US$1.00 = F$1.37 early October 1990; FEA domestic charge is US$0.149/kWh.
2) SL-13 cost F$35.00 (Oct 1990); Incandescent average F$1.45 from 5 Suva shops (Oct. 1990).
3) Electricity use for SL-13 = (16w)(1kW/1000w)(1,000 hrs)($0.149/kWh) = $2.384.

In the above case, the calculations are easy if we calculate costs over the ten year lifetime of the SL-13. After the initial purchase, the annual cost of operating the SL-13 is $2.38. The annual cost of operating the incandescent light is $8.94 for electricity plus $1.06 for a replacement light. If we use a discount rate of 10% per year (commonly used in Pacific Island planning offices), the present value of a cash flow of $1,00 per year for ten years can easily be calculated as $6.1445 either by looking it up in a table 18/ or by the formula $PW = [(1 = i)^n - 1[/ [i(1 = i)^n]$ where i = annual discount rate and n = time in years. In this case $PW = (1.1^{10} - 1)/(0.1 \times 1.1^{10}) = 6.1445$.

17/ This should be in dollars of today's value, ie ignoring the general effects of inflation.

18/ PEDP has provided books with such tables to each energy office.

The present worth of SL-13 expenditures is:
PW = initial cost + present value of future costs
PW = \$25.55 + 6.1445 (2.38) = \$40.17
The present worth of incandescent light expenditures is:
PW = initial cost + present value of future costs
PW = \$1.06 + 6.1445 (8.94 + 1.06) = \$62.51 (but see below)

However, the above calculation slightly overestimates costs for the incandescent light since the formula assumes replacement of the light every year including the first year. The total PW should therefore be reduced by the present value of one light discounted by 10% over one year (1.06/1.1 = \$0.96) or 62.51 - 0.96 = \$61.55.

Usually, the flow of costs and benefits is not equal during each period. This sort of calculation is very simple using Lotus 123 which has built-in formulas for present value 19/ with equal periodic cash flows (@PV) and a series of cash flows which may or may not be equal (@NPV).

19/ The user must be careful in using these formulas since Lotus discounts form the end of each period; examples in this paper assume that the initial purchase is made at the beginning of year 1 so Lotus calculations were modified to take this into account.

Figure 1:

Urban Household Electricity Use: Fiji (early 1980's Surveys)

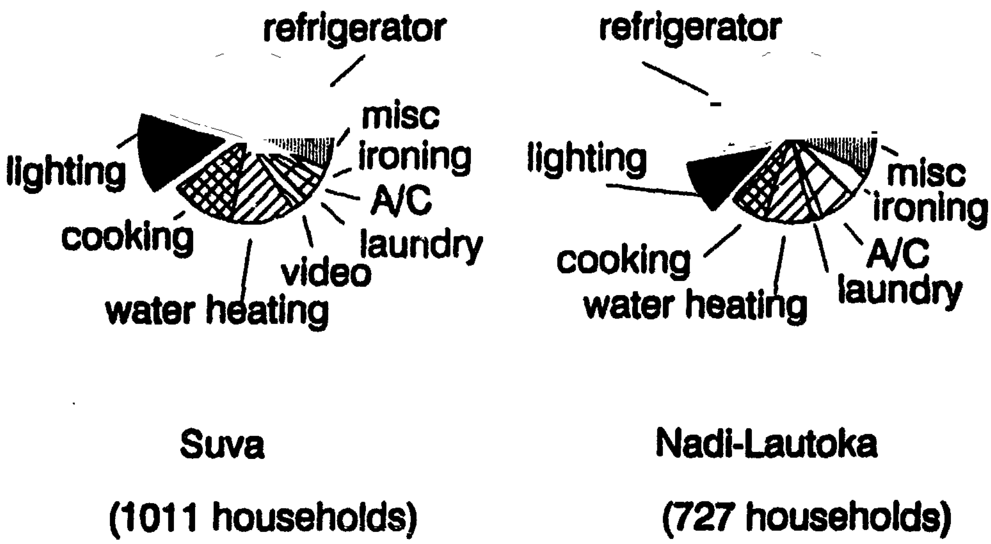


Figure 2:

Household Refrigerator Efficiency

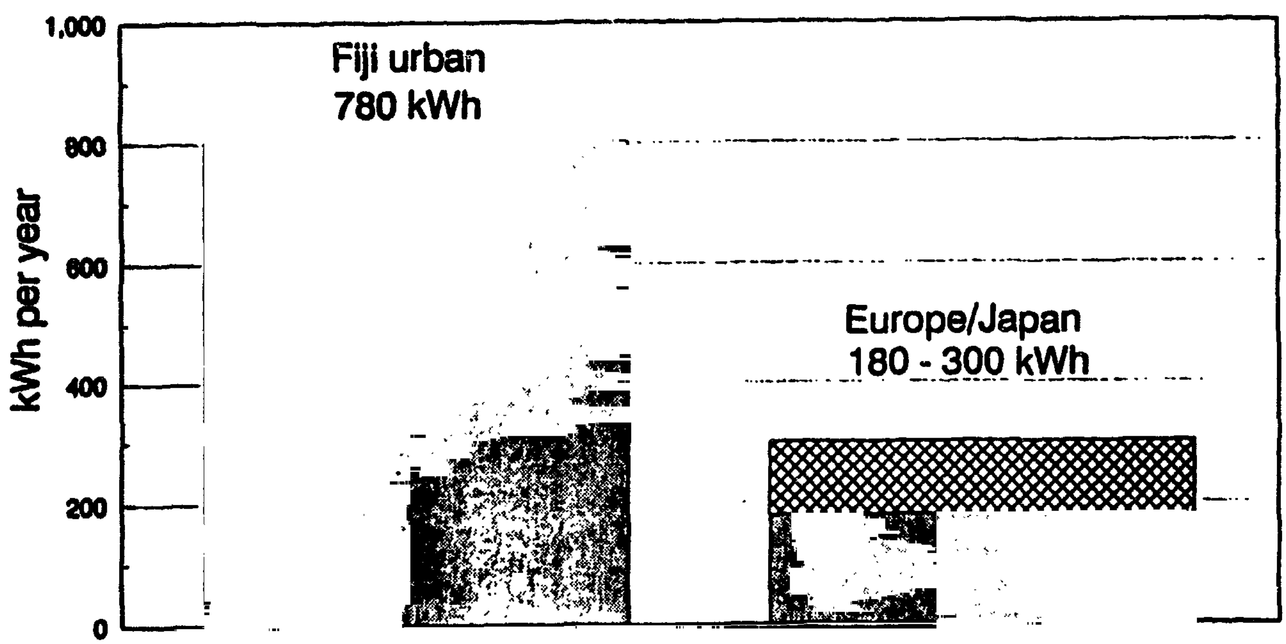


Figure 3:

Typical Efficiency of Appliances: Europe Late 1980's

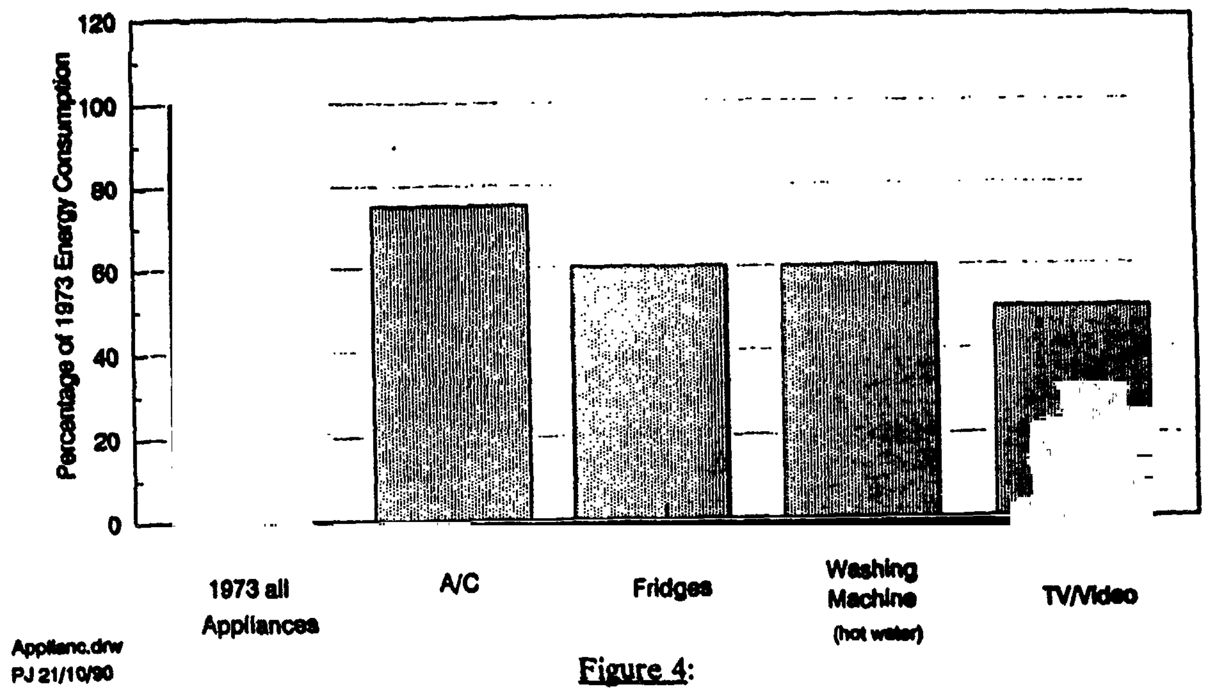


Figure 4:

Different Types of Floursecent Lamps

The three leftmost illustrations are different types of compact fluorescent lamps with US-type screw-in fittings. The standard incandescent globe on the right is drawn to the same scale.

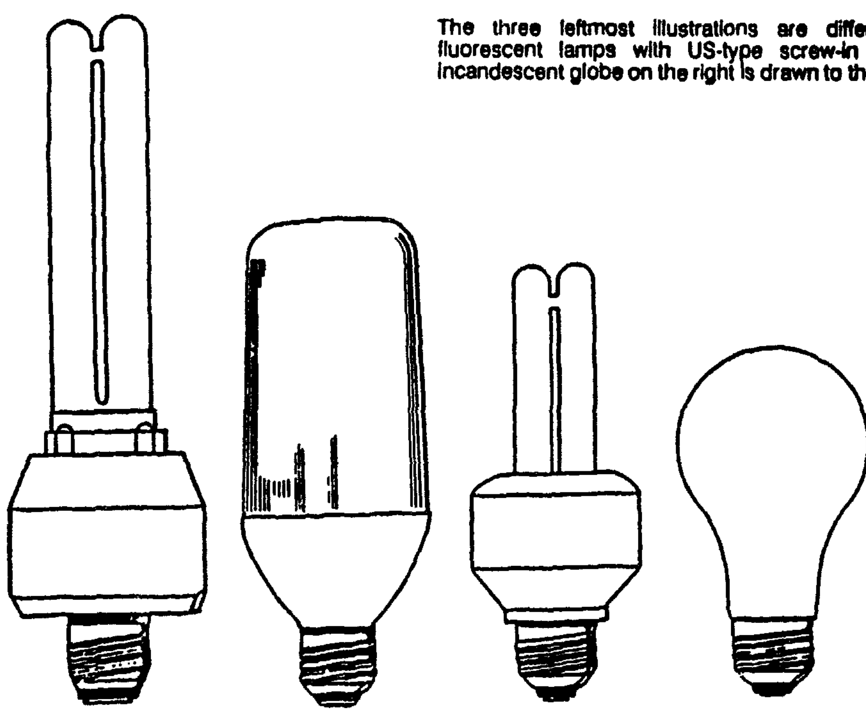


Figure 5:

Estimated Cost of Household Refrigerators (Fiji - Late 1990)

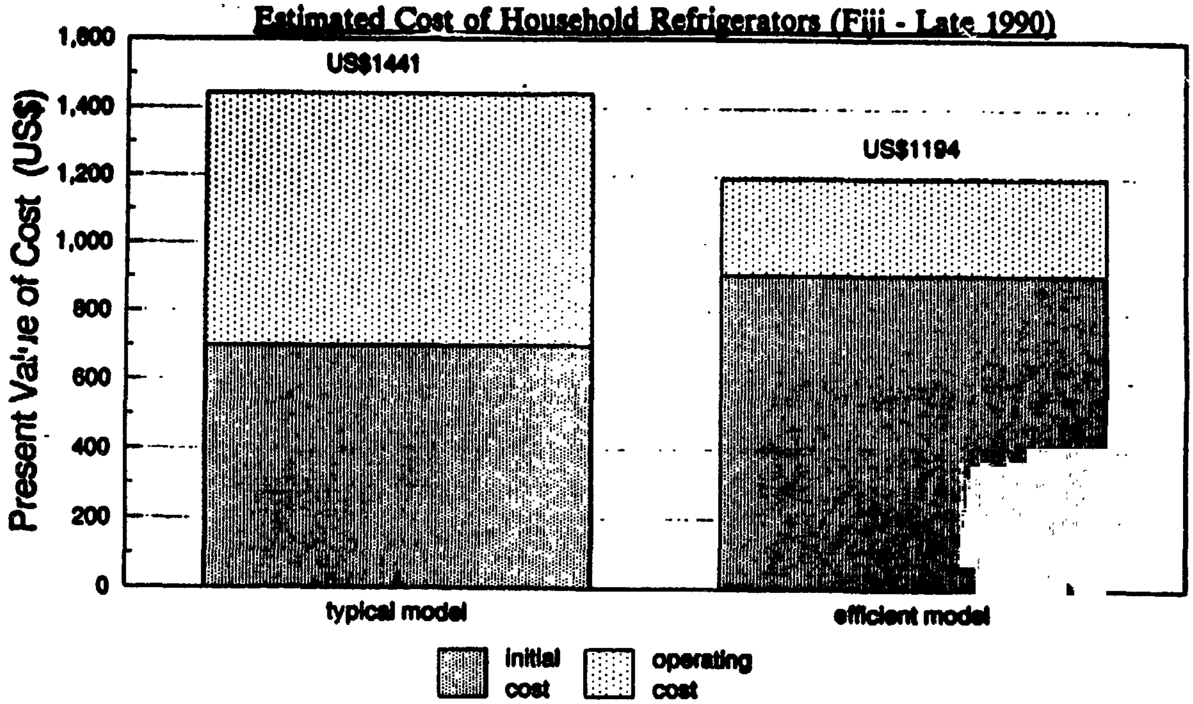


Figure 6:

Annual Cost of Lighting (Urban Fiji - Late 1990)

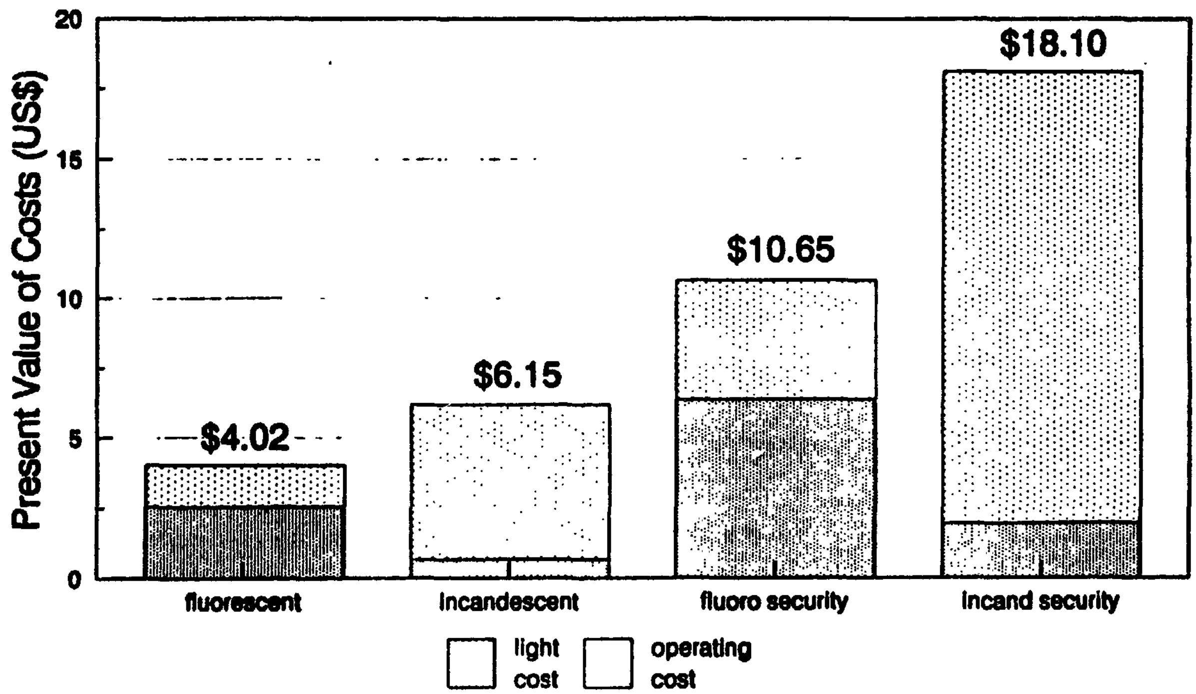


Figure 7:

Fiji (Viti Levu) Peak Load 11.11.88
(Megawatts)

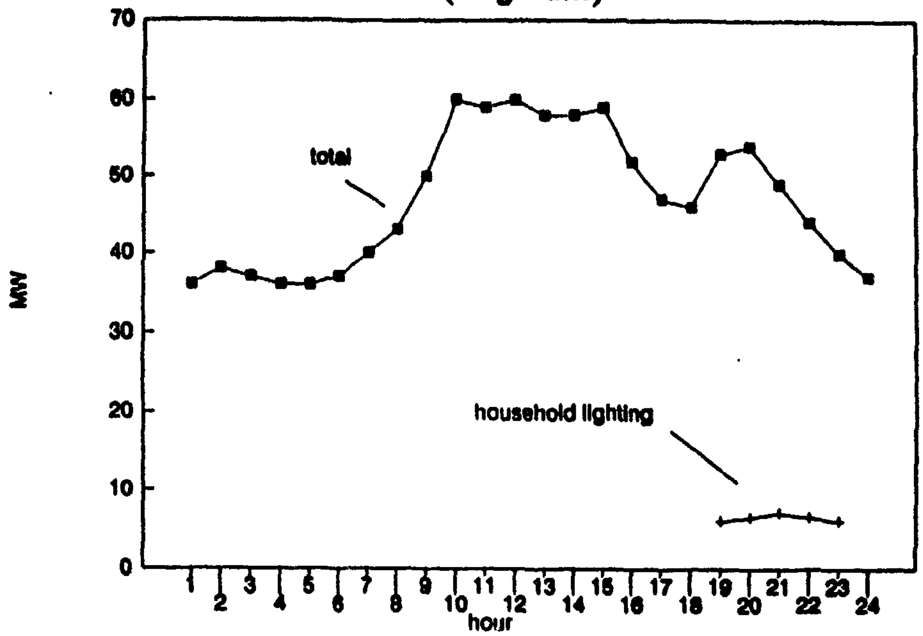
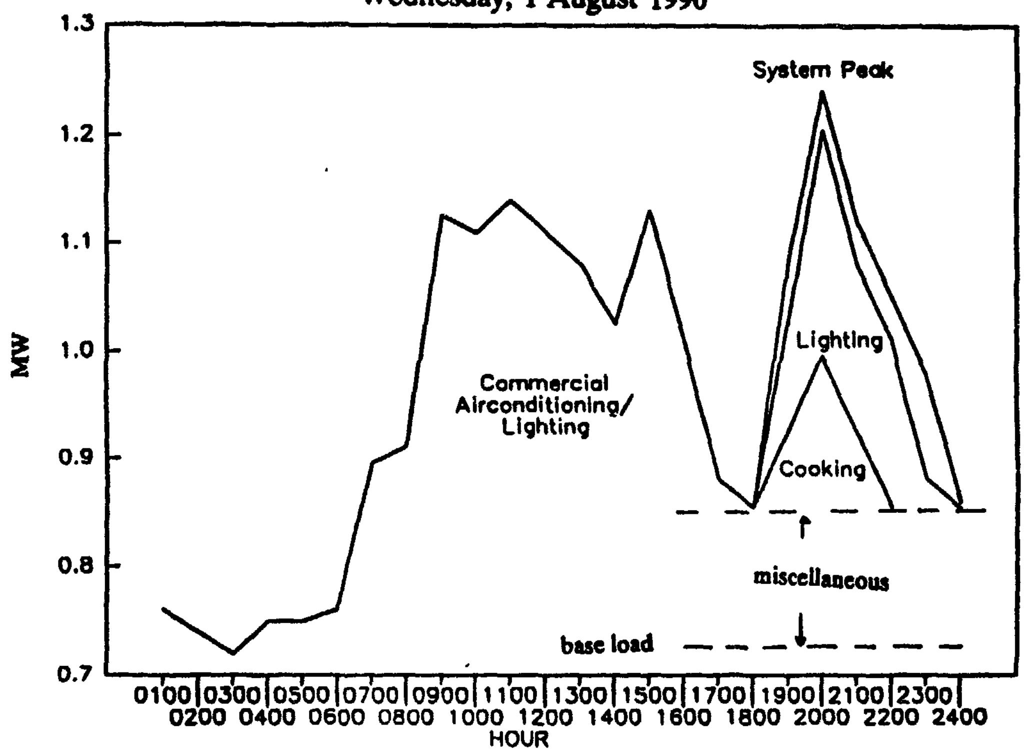


Figure 8:

Load Curve for South Tarawa
Wednesday, 1 August 1990



RURAL ELECTRIFICATION WITH PHOTOVOLTAICS: POLICY LESSONS LEARNED FROM PACIFIC ISLAND EXPERIENCE

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Introduction

Once the decision has been made to electrify a rural district, a generation technology must be chosen and the structure for continuing support provided. A number of generation technologies are possible for rural electrification. Three technologies have been used with sufficient success in the Pacific to make them worthy of consideration:

(a) small diesel;

(b) micro-hydro; and

(c) solar photovoltaics.

This paper deals with the third: generation from sunlight.

Though many renewable energy options are essentially experimental and not yet in commercial production, photovoltaic systems have been in commercial production in essentially their present form for over thirty years and is a mature technology. Their use for non-experimental rural electrification has a history of less than ten years, however, since it has been only in the last fifteen years that the cost of photovoltaic components has fallen to a level allowing domestic installations to be economically competitive with other electrification technologies such as small diesel and hydro.

In deciding whether or not photovoltaics is a reasonable technology for a specific rural electrification application, it must be compared with the other options. Useful comparison criteria include capital cost, recurring cost, availability of technical support, availability of administrative support and user acceptance.

Comparison of Individual Solar Photovoltaic Rural Electrification with Central Diesel Generation Systems

Rural electrification systems using photovoltaic power are capable of being economically installed as individual systems rather than requiring a central generation facility as is the case with hydro, diesel and other rural electrification generation schemes. It is this capability of individual installation that provides many of the unique advantages of photovoltaic systems.

Advantages of Individual Photovoltaics over Central Diesel Power

For village scale electrification, the primary advantages of individual PV systems over central diesel systems are:

(a) There is no power grid. The resulting cost savings, particularly for communities having widely separated houses, often is greater than the capital cost differential between diesel and solar power. The French Polynesian experience is that for new rural electrification it is usually cheaper to provide equivalent electrical services using individual solar than diesel with a grid.

(b) Access to land is not a problem. Obtaining land for power plants, distribution system right-of-way, transformer sites and placement for other physical components needed for central diesel systems can be a serious problem in the rural Pacific. Years of negotiation may be necessary before all land clearances are obtained. Individual systems do not require negotiation or tenure judgments.

(c) There is no requirement for fuel. PV electrification not only allows a significant savings in cost of fuel for electrical supply but often more importantly there is an avoidance of difficulty with fuel supply and storage. A common problem of isolated rural communities in the Pacific is the uncertainty of fuel supply. Heavy seas can prevent safely landing fuel, mechanical problems with boats may cause long shipping delays, inadequate fuel unloading and storage facilities can cause contamination of fuel and environmental pollution. These uncertainties in fuel supply and quality become uncertainties in electrical supply where power is provided from diesel systems. The cost of developing an environmentally safe storage of a size adequate to insure a continuing supply of fuel is substantial.

(d) Individual systems are modular and can be sized to fit individual needs making power cost truly proportional to capacity utilized. Wealthy families desiring refrigerators, videos, fans and other capabilities beyond lighting can have a system large enough for their needs while the family desiring only basic lighting need have only a small system at correspondingly lower cost. In the case of a central system, the capacity of the system is usually dictated by the demands of a few affluent consumers who rarely pay their proportionate share of the system cost.

(e) Small central systems are easily overloaded resulting in the loss of power to the entire community while overloads of individual systems result only in individual loss of power. The activation of a single large demand appliance, such as an electric fry pan, during peak demand times can overload a small village central system creating a power loss for the entire community. It has proved very difficult to control the use of such appliances and the resulting frictions within the community are not easily resolved. With individual solar systems, excess power use results in early loss of power only to the consumer using excessive power and may result in friction between the power authority and the user but not within the community itself. The power levels and technical complexity of stand alone solar systems is far less than central systems. Only a solar array, charge/discharge controller and batteries comprise the individual solar system.

(f) The power levels are low and the components simple. All three components are easily maintained and repaired by minimally trained persons. It has been observed that the higher the level of technical training a person receives, the less likely he is to stay in a rural environment. The turnover rate for persons highly trained enough to properly operate and maintain central diesel power systems is far higher than that for the minimally trained person needed for individual solar system maintenance.

(g) Overall community power reliability is higher. The failure of a component in central facility causes the loss of power to the entire community. A similar failure in an individual system is limited to one user. Furthermore, PV systems are composed of a few simple sub-systems. There are no moving parts. Diesel engines and rotary generators have hundreds of moving parts, any one of which can cause system failure.

(h) The location of houses is not fixed by a grid. It is not unusual in many Asian or Pacific cultures to change house locations regularly along with changes in the location of tilled land or for family reasons. Individual solar systems are easily moved to the new location but grid systems are inflexible once installed.

(i) The practical limit to the maximum power demand from individual solar systems is very high while central systems are severely limited by generator and distribution capacity. Individual solar systems operating from lead-acid batteries can provide very high power levels and are limited by watt hours available rather than instantaneous watt demands. Thus a small individual PV system having 120 watts in peak panel (generation) capacity can power a movie projector drawing 1500 watts for a few hours per week while a central system must be sized to generate and distribute the full 1500 watts no matter how short a time the projector is to be operated.

(j) Users can participate in system maintenance. In central systems, components requiring maintenance are distant from the user and rarely even seen. Individual systems have all components at the user's home and minor, but necessary, maintenance can be accomplished by the user rather than an outside specialist. It must be noted that it is clear from experience that few users will or can provide all maintenance for solar systems and that some organized periodic maintenance must be provided by a specialist organization.

(k) Power is available 24 hours a day at no increase in cost. Most rural central systems operate only a few peak demand hours per day since the cost of operating during low demand times is too great. Individual solar systems have continuous power available to the user so long as his use rates are commensurate with system watt-hour capabilities.

(l) Maintaining adequate spare parts inventories is easier and less costly. Large numbers of essentially identical individual solar systems requires a spare parts inventory comprised of only panels, batteries and controllers. Diesel systems require stocking large numbers of different small parts to repair engines, generators, switchgear and the distribution system. Further, different sized systems needed for different sizes of villages require different sets of parts making the spare parts management of a national scale rural electrification system very complex.

(m) **Individual solar systems are safer. In order to distribute power efficiently, central system voltage levels are high enough to be dangerous. Individual solar systems are usually 12 or 24 volts and do not constitute a shock hazard.**

(n) **PV systems do not contribute to noise or air pollution. In a small village environment, the diesel power plant cannot be economically located far from homes. Significant noise and air pollution in the village therefore exists.**

(o) **It is easy to add customers after the initial installation. With individual solar systems there is little or no cost penalty for late installations. With central power, particularly those having underground grids, the cost of adding customers after the installation team and heavy equipment have departed may be very high.**

Disadvantages of Individual Solar Systems Over Central Diesel Power

Though the advantages of individual solar systems over stand alone central systems for domestic rural electrification are impressive, there are disadvantages as well:

(a) Batteries are required with PV systems. The requirement for power storage with batteries is the primary technical disadvantage of photovoltaics electrification. Lead-acid batteries - the only economically attractive storage medium - are chemically and electrically delicate and represent the primary expense of operation and maintenance for PV systems.

(b) As system size requirements increase, the cost advantages of solar decrease. This is the result of decreasing marginal cost for increasing generation capacity with non-solar systems but constant marginal cost for increasing generation capacity with solar. Thus a single commercial installation with a large fish freezing unit having a 50% duty cycle requiring the availability of 100 kW capacity for 24 hours a day would not be a good choice for solar while 1,000 homes each requiring 300 watts of power for four hours a day for electric lighting would demand about the same number of watt hours but would be well suited to individual solar systems. Though PV systems can be designed to meet any foreseeable village electrical requirement, economic realities limit application to villages with low energy demands.

(c) In areas with dense vegetation, solar access can be difficult and system costs increased. If it becomes necessary to place the solar array at some distance from homes, the cost advantage of not having a grid is reduced.

(d) DC electricity provided by PV systems requires either special appliances or power conversion equipment. The need for special appliances results in a more limited selection of appliances and generally at higher cost. This can work to the advantage of the community, however, in that it eliminates a number of cheap but power hungry appliances such as electric fry pans or tea makers which are a frequent cause of system overloads for small community based diesel electric utilities.

System Costs: Comparing Central Diesel and Individual Photovoltaic Generation for Rural Electrification

There are two cost components which must be considered both separately and together: capital cost and recurring cost. From the point of view of the recipient of an aid project where capital equipment is provided, the primary analysis must be the comparison of recurring costs. From the point of view of the donor, capital cost is paramount. For the mature utility which must finance capital investment, both components are important.

In general, the smaller the diesel system, the more costly is each unit of electrical energy produced. Photovoltaic systems, however, tend to remain at about the same cost for each incremental change in electrical energy produced. When the two are compared, therefore, there is some power level below which PV systems are cheaper per unit of power produced and above which, they are more expensive than diesel.

This crossover point can be defined as that set of service conditions where a unit of power produced by PV is the same as that produced by a diesel plant.

Historically, the crossover point has been rising continuously since the photovoltaic cell was first placed into production. In the 1960s the only reasonable application for PV power was either where diesel power was not practical (e.g. outer space) or where power levels were only a few watt hours per day. In the seventies, PV power became competitive in remote villages at production levels of less than a few hundred watt hours per day per household. Today, the cross over is often over 2,000 watt hours per day per house in small remote villages.

Though the decision whether to go with diesel or PV is never wholly financially motivated, relative cost is certainly a major consideration. In determining the relative cost of diesel vs. PV electrification, many factors must be considered which affect capital investment and/or recurring cost.

Factors which have their primary effect on the relative capital cost are:

(a) The number of houses - The cost of diesel electrical production goes down with an increase in the number of households served since the cost per unit of electricity falls as plant size increases. PV production cost per unit of electricity is relatively unchanged with changes in village size.

(b) The average electrical use per house - Again, villages with higher per house needs will be shifted toward lowered diesel production prices while PV costs will remain about the same per unit of power produced.

(c) The average distance between houses - With a diesel system, the cost rises as the distance between houses increases because of increased connection costs and increased line losses. With PV systems, the cost is essentially the same over a wide range of separations. Extreme separations may increase the cost of PV system maintenance due to lowered labor efficiency in making maintenance visits.

(d) Climate conditions at the site - The necessary capital investment in PV panels increases in climates with higher levels of cloudiness over those with clearer conditions. Diesel costs remain much the same in different climates.

(e) Physical conditions at the site - Central system capital cost increases with increased difficulty in the construction of the distribution system. PV system costs increase with increased levels of vegetation induced shade.

(f) Type of load - Loads which have high instantaneous demands increase the capital cost of diesel systems but do not necessarily increase the cost of PV systems. PV system cost increases in proportion to energy delivered. Diesel capital cost increases with demand and its operating cost increases in step with energy produced.

(g) Land cost - Central systems require a commitment of land for a power house and for the distribution system. Individual PV systems generally have no land cost in their capital accounts.

Factors primarily affecting recurring costs:

(a) Fuel cost - The cost of fuel must include not only the actual purchase price but also a cost factor which includes transport, storage and loss due to leakage and contamination. There is no fuel cost for PV.

(b) Battery replacement cost - The same types of factors affect batteries for PV systems as affect fuel for diesel systems. There is no significant battery cost for diesel.

(c) Daily period of service - Loads, such as refrigeration, which require 24 hour power production require higher diesel maintenance and fuel costs per unit of power produced than those such as lighting which may be satisfied through operation of the power plant only a few hours per day. PV systems are inherently 24 hour power systems and are much less cost sensitive to the time loads occur.

(d) Labor cost - Diesel systems require one or more operators (according to the hours of operation) and typically one or two technicians /laborers for each village. Solar installations require one technician for each 75-100 homes which means a single technician may effectively serve several villages. The level of training required - and salary demanded - tends to be greater for central system personnel than for persons responsible for the operation and maintenance of PV systems. Administrative costs for spare parts supply, advanced maintenance and accounting support are higher for central systems than those associated with PV generation.

Non-quantifiable Factors in the Relative Economics of Central Diesel vs Individual Photovoltaic Generation

Though the comparison of system capital and recurring cost is the most important calculation in deciding which type of system to use, other non-quantifiable cost factors should also have weight in the final decision. Some of the more important of these are:

(a) The need for reliable power - There often is a cost associated with not having power when expected. The cost may be political, material or social. Solar photovoltaics, when properly designed and maintained, provides a much higher level of power reliability than diesel generation. To approach PV system power reliability, a diesel generation system must be duplicated so that one system may be undergoing repair while the other is operating. Where power reliability is less important, this factor has less weight.

(b) Probable load growth - In the rare rural district where rapid economic progress is being made, the modest levels of power which can economically be provided by a solar system may become insufficient during the economic life of the system. The added cost of installing a central system with associated grid may be a of long range economic benefit when compared to the cost of installing a PV based system then replacing it with a grid system five to ten years later. It must be emphasized that this is a rare situation in the rural Pacific of the 1990s.

(c) Willingness to accept uncertainty in recurring costs - Because the operating cost of a diesel system is tied to foreign oil prices, the long term recurring cost of a diesel system is less predictable than that of a PV system. Though PV system recurring costs are tied to battery prices, batteries have historically been much more stable in price than has diesel fuel.

(d) Training and manpower - The greater complexity and greater physical hazards associated with diesel powered central systems requires a level of training several stages above that needed for comparable quality maintenance of PV systems. PV system training may be undertaken locally with minimal facilities. Proper diesel training requires more complex facilities and often cannot be undertaken entirely locally. Though urban scale power systems are large enough to be able to afford this training, rural systems are not. As a result, it is usually necessary to accept poorly trained technicians for rural diesel system operation and maintenance. As a result, diesel equipment life is often dramatically shorter than it should be with correspondingly increased recurring costs and poor system reliability.

(e) The desires of the recipients - Experience shows that the acceptance of the users is vitally important to the success of rural electrification. If the users consider the system which has been installed to be contrary to their wishes, they will have no patience with problems and operating and maintaining the system will increase in cost. If the users consider the system to be the one of their preferred choice, they will be more lenient toward problems and will be less demanding for improved service when problems exist.

Implementing Photovoltaic Rural Electrification

Once the use of photovoltaics has been determined to be technically acceptable as a generation technology for rural electrification, the process of implementation must be considered. Included in implementation are four separate components:

(a) technical design;

(b) equipment selection;

(c) installation;

(d) operation and maintenance.

The project as a whole can fail if any one of these four steps is not properly carried out. In the Pacific, as elsewhere in the world, there have been a number of failures of photovoltaic electrification projects. Systems for lighting which have used a single low wattage panel have generally failed because the technical design is inadequate for the needs of the users. The original Fiji and early Tuvalu solar projects were generally unsatisfactory because the user's needs were underestimated and single panel systems were installed.

The Tonga EEC solar project was jeopardized due to poor quality equipment. Controllers were selected by the EEC contract administrators which had neither been tested nor ever used in an actual installation and were subsequently shown to be faulty. Fortunately the deficiency was recognized before the systems were installed.

Some early Cook Island installations were inadequate due to installations using small wires and long wiring spans which caused problems with appliances.

To date, only Tuvalu, Kiribati and French Polynesia have placed into operation any system specifically for the operation and maintenance of solar photovoltaics and have planned for long term support of photovoltaics for rural electrification. Countries without such operation and maintenance support continue to have project failure problems.

Technical Design

A project must be entirely conceived on paper before being constructed. Although it seems to be obvious, too many projects have been carried out without completing thorough designs which envision all aspects of the use of the system.

Among the various pitfalls of design, the following are important:

(a) Incorrect sizing - Not only must the total capacity of the installation fit the needs of the user but the various components, such as modules, batteries, controllers and wiring, must be properly matched. Many sales representatives for photovoltaic systems, in an attempt to keep initial costs low, tend to recommend PV systems with capacities inadequate for the required service. In particular, this has been a problem with systems containing larger energy consumers such as refrigerators.

(b) Inadequate battery capacity - It happens also that in order to save on the capital cost, the batteries are undersized which leads to more frequent replacement and higher ongoing costs.

(c) Improper pump design assumptions - In the case of solar pumping stations, malfunctions often come from not making correct assumptions of total static head or on dynamic head losses in the piping.

A proper design leads to a complete and detailed technical specification and equipment selection.

Choice of Equipment

Even a well engineered installation cannot function properly with defective components.

The difficulties do not come from the new technology: the PV panels. They are the most reliable part of the system. Batteries and controllers are the causes of most of the malfunctions.

(a) Batteries as delivered from manufacturers present two types of problems:

   (i) Low capacity - Their capacity is almost always less than stated by the manufacturer.

   (ii) Low energy efficiency - Their energy efficiency may be low, meaning that the energy available after storage is less than eighty-five percent of the energy which came from the panels. A low battery energy efficiency can be offset only by increasing the number of modules, which is costly.

(b) Controllers also can cause problems.

   (i) Poor reliability - If the controller fails, the user has a tendency to bypass it and battery failures increase due to the lack of over charge and excess discharge protection.

   (ii) Unstable operation - Controllers which do not have stable cut off points are a problem.

   (iii) Excessive power consumption - Some controllers require an excess of power for their own operation. Such controllers reduce the amount of power available to the user which can only be compensated for by increasing the available number of panels installed.

(c) Appliances must be selected for good reliability and efficiency of operation. The appliances best used with solar systems are those designed to be used with direct current from the solar system and, for several reasons, they are not only as reliable as the more common AC mains equipment but are usually more efficient users of power.

The equipment intended for use in solar systems must have been proven through experience or test to meet technical specifications and reliability requirements for the difficult hot, high humidity, salt laden environment of the Pacific Islands. This is why, as long ago as 1982, S.P.I.R.E. began systematic testing of the main components being used for solar installations. This gives us today the knowledge necessary to select the best available components to insure installed systems will meet their engineered specifications.

Regarding testing, according to the wishes expressed by the delegates to the 1985 Apia SPC/SPEC/PEDP regional meeting, the test procedures have been standardized in consultation with PEDP and several countries of the region. Let me take this opportunity to again invite the countries of the region to take advantage of S.P.I.R.E. test benches to evaluate the equipment which they intend to acquire for their own solar projects. S.P.I.R.E. will also be pleased to make available the reports of the tests which have already been performed.

Installing the Systems

An economically viable project, designed properly and using the best available components will still not function properly if the installation is poorly carried out. The installation must be made in accordance with a distinct technical specification which clearly defines the process.

Among the more common faults in installation are:

(a) Errors in panel positioning - Most installers attempt to orient solar panels without reference to accurate indicators of direction such as a compass. They rely on their own guess or that of villagers for direction. Almost always, this leads to orientation mistakes and therefore to lower power availability. The other mistake in location is inadequate consideration of shade from vegetation or structures, even from other solar modules in the same array.

(b) Wiring mistakes - Reversing the polarity of a single module in an array containing many modules is a frequent error which drastically reduces the available power from the array.

(c) Poor connections - The quality of the connections in a low voltage solar system is much more important that in 110V or 240V wiring. Poor connections tend to cause contact heating and excessive voltage drops which are detrimental to the proper performance of the installation.

(d) Improper protection for and location of batteries - This is important to safety because:

   (i) there is some risk of accidental explosion of a battery, and

   (ii) the acid in the batteries is corrosive.

At the time of acceptance of an installation, a commissioning inspection and report should be made. It must be carried out according to a specific commissioning procedure which gives the measurements and inspection steps necessary for acceptance and commissioning. This insures to the owner that the installation meets the technical specifications originally set forth.

User Education and Maintenance Organization

It is essential that the system for providing user information and the method for maintenance organization and its finance should be clearly established no later than the engineering stage of the project. No project should be begun without having made all the arrangements necessary to insure adequate user education and a proper organizational and financial structure for maintenance. You must realize that this step is an important integral part of the project.

User Education

It is out of the question to give the users of a domestic solar installation extensive technical training. However, included in the installation should be a permanently affixed plate which clearly delineates to the user the capabilities of the system installed and the directions for its proper operation.

Experience shows that installers rarely take the time to provide user instruction and as a result the users have the tendency to tinker with the installation often causing serious damage. These instructions must be posted and explained verbally to the user before commissioning.

Training of Maintenance Technicians

Technicians living near the installations should be used for basic system maintenance. It is not necessary that these maintenance technicians have extensive technical training, only the amount of training necessary to maintain that specific type of installation. Such training is provided at S.P.I.R.E. using as a base a course which has been given in IS countries of the region and has been translated into 13 local languages as a part of the "roving training course" series developed jointly by PEDP and S.P.I.R.E. in 1987 and 1988. The text of the course in French, English or any of the 13 local languages is available to those interested.

Organization and Financing of Maintenance

This is a complex problem because of the interaction of economic, technical, political and social considerations.

The problem is to organize a structure which allows:

(a) Getting from the users a periodic payment sufficient to cover the cost of maintenance and, if so desired, the amortization of the initial cost.

(b) Insuring periodic checking of installations and their repair when needed.

Several types of organization are possible using either a municipal structure or a company having a contract with the owners. All such organizations have a common set of requirements:

(a) There must be a contract between the user and the maintenance organization clearly setting respective responsibilities and fee structures. With newly electrified communities in rural districts, there are often misunderstandings about fees and what parts of the installation are to be maintained by the user and what is to be maintained from the outside. For example, it is not unusual for new users to believe that if they do not use lights, then they do not have to pay any fee. Likewise there are often misunderstandings about who is responsible for replacement of light bulbs or the repair of appliances.

(b) There must be a consistent and practical system for collection of fees. The system for fee collection must be predictable and consistent. It must include measures for punishing users who do not pay fees, usually system disconnection, and those punishments must be administered without fail.

(c) The resulting fund must be managed properly and used only for the prescribed purpose. A common problem with PV system maintenance is the long period which may pass between major repair expenditures. It is common for a PV system to work perfectly for five or more years before a significant repair cost is incurred. It is very tempting to use the repair fund for other purposes if it does not appear to be regularly needed. Of course, what happens then is when it is needed, the funds have been used elsewhere and repairs are impossible.

(d) There must be periodic maintenance by competent technicians. Though PV systems are very reliable, they must be maintained on a periodic basis for that inherent reliability to be realized. The system for operation and maintenance of the PV systems must include a process for regular inspection and maintenance of every individual system. Fortunately, the maintenance required is simple and requires little technical competence in its application. It is therefore reasonable to provide training to persons residing in the project area and contract or hire them to provide that maintenance. For more technically difficult problems, such as actual system failures, well trained technicians must be available but they can service a large number of installations from a central location since the great majority of service requirements are being met by local technicians.

(e) The system must be designed to consider political and social problems such as:

  (i) inconsistency in collecting fees - Everyone using electricity from the project must be required to conform to the same fee payment schedule.

  (ii) inconsistency in punishing users who are delinquent in paying fees - If systems are not disconnected or other punishment for non-payment of fees is not administered, fee collections will dwindle and sufficient money to continue maintenance and repair will not be available.

  (iii) the tendency to use the repair fund for immediate needs - It is very difficult for a local political body to have available to them a relatively large sum of money without their rationalizing its use for strong, immediate needs when the need for significant solar system repair may be years down the road.

  (iv) discrepancies between fees charged and actual costs - When the fees are set by local political bodies, there is great pressure to set fees which are too low. The result is invariably a financial crisis about five years into the project when the first battery replacements are necessary. If there is strong social or political reason for lower fees than are needed to cover costs, subsidies should be arranged for immediately instead of waiting for the all too predictable crisis to develop.

Conclusion

Unfortunately one must recognize that there are very few cases where all the steps which have been described here have actually been carried out. Most of the solar installations in the Pacific have been carried out without prior economic study, without adequate technical design and specification, without proper installation specifications, with equipment which has not been tested, without meeting commissioning requirements and without taking into proper consideration the continued operation and maintenance of the project. As a result the percentage of failures is unacceptably high. That it is not higher is a tribute to the basic soundness and reliability of photovoltaic technology. The technology is clearly the best choice for a large number of rural sites in the Pacific where electricity needs are low.

THE NASOQO MICRO-HYDRO POJECT

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Introduction

The Fiji Department of Energy was founded in 1981. One of its first tasks was to determine the technologies appropriate to Fiji rural electrification. Three technologies were considered technically appropriate: (1) small diesel; (2) individual solar; and (3) micro-hydro. In addition small steam plants operating from coconut husks or wood waste were considered a reasonable option though experience was limited. A major problem with rural electrification is the unknown cost of installing, operating and maintaining the electrical systems. Considerable experience with small diesel sets had been gained by the Fiji Public Works Department with over a hundred villages electrified under their programme. Though solar and micro-hydro projects had been done in rural Fiji, the projects were not designed to fit into a larger scale electrification programme and the costs were poorly known.

In 1982, Fiji DOE decided to provide a small steam plant, solar systems and a micro-hydro unit to villages willing to accept those technologies, pay for some of the installation cost and provide for the cost of continuing maintenance.

USAID was contacted and agreed, through a series of small grants, to provide $20,000 for solar and $25,000 each for hydro and steam programmes providing suitable villages and appropriate equipment could be located to make the schemes financially and technically practical.

Villages which had previously requested electrification by hydro were reviewed and the most promising ones visited. Nasoqo was the village which had the most characteristics sought by DOE and was selected to have the first chance to receive the micro-hydro installation.

The Nasoqo Village

The village is located in north central Viti Levu, the most rainy part of the main island of Fiji. The nearest road is approximately seven kilometers from the village and access is either by following the Nasoqo river from the road or an overland trail paralleling the river. The river route is not difficult though the river must be crossed over 20 times and becomes impassable when the river has risen even moderately above its usual level. The land route is several kilometers longer and has many segments of steep jungle trail and several segments of deep mud which makes it a difficult trek. A few horses are available in the village for carrying freight but most transport is undertaken by the villagers themselves.

Nasoqo is a community of about 250 persons and 31 continuously occupied houses. The fact that all non-traditional construction materials have to be packed in on foot has kept house construction mostly traditional with almost all houses using split bamboo for walls though metal roofs are common.

What cash is available to the community either comes from family working outside or from the sale of small quantities of agricultural products through markets in Suva to the south or Tavua to the north.

Nasoqo is situated in a valley with steep cliffs on three sides and a gradual slope up to the highest point in Fiji to the north. Several water falls are nearby with the largest about one and one-half kilometers from the village center. The smallest significant falls is about 200 meters from the village.

A U.S. Peace Corps volunteer, Stefan Pakulski, had been assigned to the village in 1982 and assisted greatly in both communicating between the village and DOE and in carrying out the project.

Community Involvement

Because considerable commitment was required from the village, after Nasoqo made their request for the hydro installation, several meetings were held in the village with full community involvement. At the meetings, the village was carefully informed about what they would receive: a five kilowatt plant which could provide lighting at night and possibly other uses during the day but would be very limited in its capability to provide power to large demand appliances like irons, toasters and electric kettles.

The village was told that they must provide F$150 per house to be wired or $4,500, whichever was the greater, guarantee a payment of $5 per month for maintenance and provide all unskilled labor for the installation which was estimated at about two man years.

At the third meeting, which was held over the 1983-1984 New Year's holiday, the village agreed to all conditions and proposed to form an electrification committee with a bank account in Suva requiring signatures of both a village and a DOE official. Fiji DOE agreed to commence the design work as soon as F$1000 had been deposited though material purchases would not begin until F$3000 had been collected.

The F$1000 was almost immediately deposited and design work commenced. Over the 1984 Easter holidays, the remaining funds were collected and $4650 was deposited in the Nasoqo Electrification Account.

Design

The initial design team was the author (then Director of Fiji DOE) and a Peace Corps volunteer with an engineering degree, Kurt Conger, who was assigned to DOE.

During the six month period when negotiations were taking place between the village and DOE, a preliminary site survey was made and the small, close waterfall was selected as the primary site. The older members of the village agreed that the stream had never run dry in their memory and that its level was rarely lower than what it was at the time of the visit (which was during a long dry period). A temporary wooden flow measuring weir was installed and measurements were made during the dry season for about six weeks. Flow was determined to be too low for continuous 5 kW operation but at low flow periods sufficient water was available for six hours of operation if water was collected behind a small dam.

After the project was begun, a team from the Mineral Resources Department visited the site to determine if the geology was suitable for a small storage pond and a small concrete dam. Several possible sites for the dam were considered. The best site was in a narrow gorge with solid rock for anchoring the dam on both sides though it required a relatively long penstock run of about 450 meters. That site was selected by the design team.

Shortly afterward, a survey team from the Department of Lands visited the site to provide a detailed contour map and to mark a level line from the dam site to the cliff so as to show the upper limit for the penstock installation.

The head available was 60 meters and a Pelton turbine was determined to be the most cost effective design.

The initial specifications prepared by the author included a concrete dam approximately two meters high, a buried plastic penstock with steel sections anywhere the penstock was exposed, a pelton wheel turbine, and a 1500 RPM brush type single phase 240V 5OHz alternator with automatic voltage regulation. Mr. Conger was generally in agreement with those specifications though he expressed concern that a brush type alternator required more service than a brushless type which he considered to be a better choice.

No governor was to be installed as a mechanical governor was far too expensive for such a small system and the author considered electronic governors as too unreliable. The system utilized to prevent wide speed variations was to arrange light switching so that if the interior lights were turned off, an incandescent exterior light of equal load to the interior fluorescent lights would be automatically turned on. Since the village had stated that they would not want continuous power nor would there be capacity for both lights and refrigeration, this was considered adequate at the initial stage of Nasoqo electrification. An electronic load controller could be installed easily at any later date should the situation change. Also since the system was to be operated only from dusk to 11 pm or 12 midnight except on special occasions, it was considered unlikely that the house lights would be turned off before the system was shut down, making the relatively short life of the incandescent globes (when compared to fluorescent lamps) unlikely to be a problem.

Mr. Conger agreed that a mechanical governor was not practical for this small a system but he did not share the author's opinion about electronic controllers being unreliable and felt that even with the load switching scheme there might be serious governing problems but agreed that it was reasonable to try it and if it didn't work well to then install an electronic governor. The electrical design included generation at 240V 5OHz single phase with no voltage transformation in the system since the power house would be just across the river from the village. The village agreed to having in each house two or three 20 Watt fluorescent interior lights, one exterior incandescent light per house and a power point with the current limited to 0.5 Amperes for radios or other low demand appliances. Village area lighting would be provided by low pressure sodium vapor lights on poles.

Though the village had agreed to provide all labor, the electrical wiring installation would have to be done by trained electricians. Although the Fiji Electricity Authority (FEA) would, by law, have to inspect the installation for code compliance, it could be done by a private contractor or the Public Works Department. Since FEA had, at that time, responsibility for rural electrification on Viti Levu, DOE decided that they should do the work, partly to familiarize their staff with rural electrification using small hydro and partly to determine their performance in such a project. FEA was asked to design the electrical system and to provide an estimate of the total cost. The FEA design and an installation quotation for labor and materials of $11,000 was approved in May, 1984.

The trial programme was intended to as closely as possible duplicate the conditions of an installation under a full scale rural electrification programme. In a full scale R.E. programme for hydro development, it would be necessary to have a local engineer on site during the construction period. For this project, no local engineers were available for the estimated six months of construction time, but a Peace Corps volunteer, Mike Smith, who was a civil engineer, could be made available. He was contacted and agreed to participate in the project. Using preliminary designs from the author, Mr. Smith produced a detailed design for the dam and estimated the materials and labor requirements for the civil works.

Materials Purchase

FEA made all electrical purchases except for the alternator and alternator switchgear which, along with all other materials purchases, were made by DOE.

Cement, reinforcing bars, lumber, metal roofing and plastic penstock piping are manufactured in Fiji, making those items immediately available. PWD was able to supply the few sections of steel pipe and gate valves needed for the penstock so those were also immediately available. FEA stocked all the electrical materials needed so there was no purchasing delay. Only the hydro plant and associated alternator had to be obtained overseas and required any significant lead time.

After considerable correspondence and visits to two small hydro manufacturers, Tamar Designs of Tasmania was selected to provide the turbine, spear valve, alternator and alternator switchgear. Delivery was to be in June following full tests of the assembled system on a test bed at the manufacturer's plant.

Since the turbine and generator would be the last thing installed, it was not necessary to wait for its delivery and construction was scheduled to commence immediately upon receipt of civil works construction materials. FEA was instructed to proceed with their installation.

Construction

Considerable time pressure was present since the author's contract was up in mid-July and he did not intend to renew since there were qualified local persons available to fill the position. All three Peace Corps volunteers involved would complete their contracts in September making it desirable that the project be completed as soon as possible.

Though the author was adamant that the conditions of the Nasoqo installation would be as close as possible to those found in a full scale R.E. programme, the Royal New Zealand Air

Force offer of free helicopter transport of materials the seven kilometers from the road to Nasoqo would save much back breaking labor and weeks of precious time so it was reluctantly agreed to accept their offer. Over a period of two days, all materials were brought from Suva by truck to Naqelewai, the closest village to Nasoqo on the road, and delivered by helicopter to the Nasoqo with only one broken power pole and the loss of a few lengths of plastic pipe.

The Peace Corps engineer, Mike Smith, lived in Nasoqo during the construction of the project and Kurt Conger spent several weeks on site as well. The author visited the project several times for approximately two days each visit though since actual construction did not begin until July, the author was not available to assist beyond the initial stages.

It was clear in July, that construction could not be completed by September, the month the Peace Corps Volunteers were scheduled to depart. All three of the volunteers involved in the project, Stefan Pakulski, Kurt Conger and Mike Smith, demonstrated their commitment by agreeing to apply for a two month extension in order to see the project to completion.

The villagers worked as promised, often neglecting their gardens - their main source of food - and Yaqona patches - their main source of money - to spend time on the project. As with any project operating under time pressures, there was friction and problems but construction of the electrical wiring and the civil works was completed by November and a formal dedication ceremony scheduled. The turbine and generator were installed and just prior to the scheduled dedication were tested. Though there was no problem with the turbine or the hydro components, the electrical system did not work. The alternator could not be brought to adequate power levels without becoming unstable. During the tests, carried out under great time pressure and with inadequate test gear, the exciter winding of the alternator was destroyed and the automatic voltage regulator was damaged and the system could not be operated. The dedication was cancelled and the alternator packed to Suva for repair.

Repairs were completed within a week and the system reconnected. With the repaired voltage regulator, and without the pressures of a close deadline, the system was made operational to the point of powering street lights and some village lights.

Unfortunately, the alternator still could not be brought to full power without a problem and the system was capable of operating only the street lights and one light per house without instability.

After the problems with system stability became apparent, it was decided by DOE that an electronic load controller would be of use in the hope that by applying a full and constant load to the alternator that stable power would be obtained. The controller arrived in Fiji in early 1985 and the author visited the village in March and installed the controller. There was no change in the operation of the system and the author concluded that the problem was a mismatch between the exciter and the automatic voltage controller circuit causing oscillation of excitation. Fiji DOE agreed to look into the replacement of either the AVR or the alternator and called on an experienced local electrician, Mr. Bill Smith, to visit the site. The author accompanied Mr. Smith on his first visit and agreed with his recommendation that both the alternator and the AVR be replaced with a matched set. Several errors in the FEA wiring were found and repaired, though none contributed to the instability problem. The system remained partially operational but was formally dedicated in May.

Shortly after the formal dedication, the alternator exciter again burned out and the decision to replace the alternator and AVR was made. Since only a two pole, brush type alternator was available in a reasonable time, that was selected as the replacement for the four pole brushless unit, though it was recognized at the time that the life of the system would be limited by the life of the bearings in the new alternator which were heavily stressed both by the high tension belt and the 3000 RPM rotational speed of the two pole alternator.

In late 1984, the new alternator system was installed and placed into service. For the first time, full power could be obtained from the system and the Nasoqo project could be considered completed.

In September of 1985, Nasoqo was notified that further repairs would be fully the responsibility of the village and that no further financial support could be expected from the Government.

Operation Under the Village Committee

The collection of monthly fees was terminated only a few months after they were begun. It was decided by the village that it would be better to raise the necessary repair funds when needed rather than collect periodic payments. This system has worked, though considerable time delays between the need for repair money and its collection have occurred making repairs even slower than before.

Problems with the system between 1985 and 1988 were simple in nature but involved considerable time in their resolution. The first problem was the failure of the drive belt. The special, high efficiency flat Dacron belt was unobtainable in Fiji. It took villagers months to locate a source and additional time to get a belt to the village. By late 1987 all the street lights had ceased to work due to lamp failures. Again, several months and several trips to Suva by villagers were necessary before replacements could be located.

The electronic load controller failed in 1988. It was only at higher power levels that the controller became unstable, so the system continued to be operated by the villagers at reduced power after the failure occurred. The problem was brought to the attention of the author during a chance conversation with a Nasoqo villager and he visited the site in 1988. The load controller was disconnected and the village decided not to spend the $800 to $1000 necessary for repairs but to operate the system on a fixed time schedule. All lights would be left on during that time so there would be no load fluctuations and speed governing would not be necessary.

Operation on that basis was maintained until mid 1989 when the bearings of the alternator failed and the unit was packed out for repair.

Project Overview

Despite the problems, the Nasoqo project is considered a general success because:

(a) the villagers consider it a success and have continued to operate and repair the system long after it was abandoned by the Government;

(b) the thoroughly documented history and cost of the project fulfills the initial goal of the DOE which was to determine the requirements of labor and funding necessary to implement village scale hydro;

(c) the project concept is replicable in other villages and can be considered a useful model for village micro-hydro projects.

Lessons Learned

(a) It is possible to construct high quality village scale micro hydro systems at a life cycle cost comparable to other rural electrification generation technologies.

(b) The project could not have been carried out without the full financial and labor participation of the village. It is imperative that the village be fully committed to the project. The initial labor requirements for micro-hydro are several times greater than that for diesel or photovoltaic electrification and the village must understand that it will be necessary to divert a large part of their labor resources to the project for several months. Further, they must be made aware that while they are saving money in the purchase of kerosene, they will have to ultimately spend that and possibly more on the upkeep of the system.

(c) A full time construction boss must live on site. Though the design of the civil works and electrical systems can be done away from the site, someone must be continually at the site to interpret those designs and to supervise their implementation. Because communication is the main problem, local language proficiency is more important than strong technical qualifications though practical knowledge of quality construction procedures is necessary.

(d) Site surveys are necessary but can cost a major percentage of the total project budget if not properly managed. Further, for the final design to be economically acceptable, it requires persons having specific knowledge and experience in the design and construction of micro-hydro systems - hydro engineers only familiar with larger systems used for integration into grids do not usually provide economically acceptable designs.

(e) Though the distribution system and wiring must be of high enough standard to be safe, it is not necessary that a system which delivers only a few hundred watts per house be installed using urban standards developed for much higher power levels. In Nasoqo, the cost of the reticulation was far higher than expected partly because of the application of unreasonable administrative charges by FEA and partly because of adherence to excessively high standards of installation.

(f) **For repairs to be carried out in a reasonable time, the village must have a source of spare parts and technical assistance.**

(g) **At least one repair trip by a technician and several months of system down time could have been avoided if minimal training in the operation and repair of the electrical system had been provided responsible villagers.**

Policy Implications for General Rural Electrification Using Micro-Hydro

The Requirement for Specialist Teams

The primary problem with single micro-hydro projects is the cost of the site survey and subsequent system design. Survey and design charges can easily exceed the cost of the entire physical plant. While such charges for one or two projects can be covered through aid funded consultancies or, as in the case of Nasoqo, through the use of overseas volunteers, generally using micro-hydro for village electrification requires the establishment of a local team trained specifically in micro-hydro survey and design.

Experience indicates that the survey and design phase and the construction phase are each about six months long, so one person responsible for site surveys and system design and another responsible for construction should complete two projects per year. In Fiji, for example, this would reduce survey, design and construction supervision costs to about US$3000 per project, an acceptable amount.

A technical team should also be established for repair and maintenance. This team should be equipped with adequate portable test gear and a spare parts supply to allow most repairs to be made in one visit. In Nasoqo, each repair required at least two trips: one to determine the problem and another to bring in repair parts and actually make the repair. Some problems required three and four trips when there was the need to make tests for which the technician was unprepared. Time delays of months and high repair costs due to added travel time are the result of this lack of preparation for predictable repair problems.

Repair Parts Supply

System designs should not include components difficult to replace or repair locally. The use of the special flat drive belts in the Nasoqo project resulted in many months of power outages and considerable frustration to the village. After unsuccessfully trying in Fiji to locate a local source or even the address of an overseas source, the village finally wrote to one of the former Peace Corps Volunteers in the USA to ask him for help. Fortunately, the volunteer was still very interested in the project and not only 1) provided the address, but personally ordered replacement belts from Australia for immediate shipment to the village.

Prior Testing of Systems

The initial technical problem with the Nasoqo system would not have been so serious if the system had been tested prior to installation in Nasoqo and the problem uncovered where test and repair facilities were available. Actually, the hydro system manufacturer had agreed to fully test the assembled components at his facility before shipment but delivery pressures prevented the completion of the electrical load tests. The special loading and unloading characteristics of small hydro electric systems cannot be easily duplicated by any other than a hydro type source of power. If a number of micro-hydro installations are intended, the modest cost of a pumped water source to power the hydro turbines for pre-installation testing is well justified. The cost of such a test bed could have been met from the Nasoqo project repair bills, which would have been avoided had tests uncovered the problem before installation.

The Development and Enforcement of Rural Electrification Installation Standards

As noted above, the low power levels and limited scale of village rural electricity supplies allows the safe use of installation standards which are less stringent than those used in urban systems. Standards should be set to insure that minimums are met, however, and a rural electrification authority should be empowered to insure that they are enforced.

A BRIEF COMPARISON OF GRID EXTENSIONS, STAND-ALONE DIESEL GENERATORS, AND PHOTOVOLTAIC FOR RURAL ELECTRIFICATION

Chris Cheatham
PEDP

Introduction

In most Pacific Island countries and in developing countries elsewhere there is considerable political pressure to electrify rural areas. However, rural electrification schemes in the Pacific region often cost more to operate, and provide fewer real benefits to rural people than the political leaders who promote them (and the rural recipients themselves) initially expected. False expectations for rural electrification arise from a variety of sources:

(1) National planners often make simplistic cost assumptions for rural electrification based on power system costs in urban areas. Where there is little experience with rural power supply, it is easy to overlook the additional costs related to access to remote areas, lack of local expertise, lack of local infrastructure, and additional administration that rural electrification involves, compared to power projects in urban areas. These costs, however, are very significant; they can double or triple the per-kw cost of rural power projects (especially isolated hydro or diesel stations) compared to urban power projects. For example, on-site technical expertise is required for construction and operation of a rural (or any) power project; rural villagers are usually given bare-minimum training (if trained at all) in daily operation procedures but are not qualified to handle technical problems. Outside technicians have to make special site visits at considerable expense to carry out maintenance tasks that would be routine in an urban area. Due to this expense, local operators "make do" and put up with problems much longer than they should, or until a major breakdown occurs. When a breakdown does occur, an outside technician usually must visit to diagnose the problem, spare parts have to be shipped for replacement or repair, and the repaired equipment has to be reinstalled. Each step can take weeks or months, depending on the remoteness of the site.

Thus rural power systems operate less efficiently than urban systems and break down more often and for longer periods. Construction costs are higher. The initial construction and operating budgets for rural electrification projects, however, are frequently estimated on the basis of urban power system costs and are usually exceeded.

(2) Promoters and recipients of rural electrification often assume that a new isolated rural power supply will equal the quality and reliability of the urban power supply, and that electrification alone will bring to rural areas the improved lifestyles and higher incomes of urbanization. A rural area is characterized by low density of electricity demand. In isolated areas, electrification properly designed to cater for the mainly domestic demand will not provide the same quality of power usually provided to central urban systems which cater for domestic, commercial, and industrial demand (i.e., a 24 hour/day power system capable of meeting any reasonable demand, with limited supply interruptions) even if remote-area training and access problems could somehow be overcome. Where there is no substantial night-time load, for example, an isolated diesel station could not provide 24 hour/day power, due to the high wastage of fuel in lightly loaded engines. Also, voltage regulation in small power systems, which are subject to wide fluctuations

in load, is more difficult than in large ones, and supply interruptions can be expected to be more frequent, because the investment required to provide a high degree of reliability (i.e, duplicate transmission circuits, reserve generating capability, etc.) is not justified by the low level of sales typical of small isolated power systems.

Transmission extensions which connect a rural area to the urban grid are exposed over long distances to sometimes rugged terrain and are more vulnerable to failure and poor voltage regulation than the urban transmission system.

In sum, the quality of an isolated rural power supply in most cases will not match that of an urban system 1/. Electrification can provide for certain rural needs but will not make rural life more like urban life. Moreover, where rural electricity is not provided free 2/, consumers will have to pay cash for what they consume. The extra cash burden for those on a limited income could well outweigh the benefits that electricity was expected to provide 3/. Since there is no evidence that rural electricity by itself leads to increased incomes for villagers, its usual effect on rural lifestyles is small or even negative.

(3) The institutional problem of managing rural electrification schemes is usually underestimated. Though the political importance of rural electrification is high, few countries in the region have set up effective institutions capable of planning and constructing rural electrification schemes. More importantly, some countries have not decided which agency inside or outside of Government should take responsibility for completed schemes. With no clear administration, newly-completed schemes are neglected and fall quickly into disrepair. Setting up an effective administration for rural electrification is usually an uncounted cost.

(4) Overseas lenders and aid donors (and their consultants) often "push" rural electrification schemes that are beyond the countries managerial and financial capabilities to handle through the schemes useful life. Rural electrification properly matched to rural needs doesn't necessarily involve a large investment in new infrastructure, since alternatives include not only grid extensions, stand-alone hydro, and stand-alone diesel, but also photovoltaic (PV). PVs, though often overlooked as a rural electrification option, are appropriate in rural areas where electricity serves a light domestic load, such as 2 or 3-fluorescent lights and a radio per household and communal videos, plus a small amount of refrigeration. PV units (consisting of two or more solar panels, a controller, one or more storage batteries, minimal house wiring and fixtures per household) are installed as stand-alone systems on each building (house or community hall) and do

1/ An exception might be a well-designed micro-hydro station in an isolated area, which would normally run 24 hours/day. Micro-hydros, however, are almost always run-of-the-river type schemes, dependent on rising and falling water flows, and have very high initial costs compared to equivalent diesel stations or most grid extensions. Their cost is not normally justified to supply mainly domestic demand.

2/ No country in the region has a policy to provide free electricity to anyone, but because of low flat rates and non-enforcement of monthly collections, electricity in some rural areas is virtually free to consumers.

3/ There are cases of 11 kV grid extensions into rural areas around Port Moresby (Papua New Guinea) and elsewhere that are wholly unused save for one or two street lights because not a single villager elected to pay the connection fee to put power into his house.

not require any other infrastructure 4/. In remote areas with a light load, PVs can be a much cheaper and more cost effective means to provide electricity than stand-alone diesels, micro-hydros, or grid extensions.

However, overseas donors and lenders, and the consultants who work for them, often specify large-investment rural electrification projects (usually grid extensions) in cases where PVs might have been more appropriate. An example of such a scheme in Kiribati is analyzed below. The costs or investing in a rural electrification project that is bigger and/or more sophisticated than can really be justified by local demand (and reasonable expectations of future growth) are multiple. First, the investment cost itself will be larger than necessary. Secondly, and more important in the long run, the investment will be chronically under-utilized and will therefore require higher operating and maintenance costs than would otherwise be necessary. A stand-alone diesel generating station, for example, will be lightly loaded for much of its operating life and will therefore run inefficiently and be subject to more-frequent breakdowns than a properly loaded machine. An 11-kV transmission line will require substantial annual maintenance (usually 2% of its initial cost, as a rule of thumb) even if it is lightly loaded. The consideration of relative operation and maintenance costs for rural electrification projects is especially important in the case of grant aid-funded projects, since costs after the initial installation are usually the responsibility of the recipients, not the donor. Thirdly, the financial cost to the consumer of maintaining a rural electrification project that has been "over-specified" will be higher - perhaps much higher - than would otherwise be necessary. This will discourage consumers from utilizing the investment or enjoying the benefits that electrification was expected to provide.

Rural electrification projects in the Pacific Islands region are too often promoted without seriously investigating what the rural consumers' actual needs are or what they can afford, hence projects are built which remain woefully under-utilized for years because expected demand fails to develop. Countries should adopt a realistic outlook on the costs and benefits of rural electrification, subject all rural electrification proposals to careful review and give full consideration to simpler, cheaper technical alternatives to proposed projects, even if the project has already been fully specified by an outside consultant, lender, or donor.

The Rural Domestic Consumer of Energy

In non-electrified rural areas, energy use is dominated by (often limited solely to) households which rely mainly on biomass for cooking, kerosene for lighting, batteries for torches and radios, benzene for ironing, and (in coastal areas) petrol for marine transportation and fishing. Electrification introduced into such an area would clearly be limited to household lighting, a small amount of refrigeration, and radios/videos. Load growth beyond these small domestic uses would await the influence of outside factors such as increased income from remittances from relatives living overseas or in town, commercial or industrial development, or increased Government activity in the village. Numerous studies 5/ have shown that electrification is only one of many factors

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4/ Technically, PVs may be constructed as centralized systems (i.e., a central array of solar panels and battery storage, attached to a device to "invert" the 12V or 24V DC power from the batteries to 415/240V AC power for distribution to consumers via overhead or underground cables) but such systems are far more expensive, much less reliable, and output is less than individual-household PV systems designed to serve the same end-uses, and are not recommended.

5/ See, for example, Rural Electrification for Development Policy Analysis and Applications, Mohan Munasinghe, Westview Special Studies in Natural Resources and Energy Management, 1987, and Developing Electric Power.- Thirty Years of World Bank Experience, Hugh Collier, World Bank, 1984.

associated with the economic development of a rural area, with most studies indicating that electrification more often follows development rather than leads it; therefore, none of these "outside factors" is likely to be influenced significantly by the presence or absence of electricity in the village. Rural electrification planned for such a village should be designed to meet the present and discernable domestic end-uses of lighting, radios and videos, and a small amount of refrigeration.

Rural Domestic use of Electricity and the Cost of Appliances

Appliances owned by households in non-electrified rural villages are few: several kerosene lights, battery-operated torches and radios, perhaps a benzene iron. Before a household can make use of electricity from any source, it must also meet the cost of purchasing new electric appliances, a cost which can inhibit consumption of electricity in a low income household as much as the cost of electricity itself. It should not be expected, for example, that a newly-electrified rural area would show a rapid increase in domestic refrigeration, because refrigerators are beyond the means of many households. A minority of households may purchase refrigerators and share the space with neighbors, or a refrigerator (or freezer) might be purchased by the village as a whole for use in the community hall, etc., but the rural domestic "saturation" of (percent households owning) refrigerators will be much less than seen in a high-income urban area. Similarly, electric kitchen or shop tools, videos, stereos, irons, even light fixtures are all expensive, and will not be purchased widely by low income rural consumers. Experience has shown that income levels are the prime limiting factor to domestic appliance ownership, and until income levels change, there will be no dramatic increase in domestic electricity use beyond a few basic low-power needs like lighting and radios.

There is a common, but fallacious, assumption that the supply of electricity in an area will engender a demand equal to it; in other words, that when electricity is available, consumers will find the ways and means to consume it. There is very little evidence to support this assumption. While most planners of rural electrification, including some in large multilateral organizations, might agree that rural domestic consumption of electricity will be low immediately after electrification, many are surprised that the low level of demand often persists well into - or throughout - the working life of the project. What they overlook is that rural lifestyles and incomes are not the same as urban lifestyles and incomes, and that electricity in itself does little to transform them.

Costs and Benefits of Grid Extensions

For rural supply of 24 hour/day power of a quality closest to that of an urban system, a transmission line connecting a rural area to the urban grid is the only option (with the possible exception of well-designed micro-hydros with access to adequate and reliable flows of water 6/). Maintenance of a transmission line is far less problematic than maintenance of a stand-alone diesel, for example, and has no technical difficulties under light-load conditions. A transmission line can supply any reasonable demand that consumers may place on it.

Trans. ission lines are limited in the Pacific Islands region by geography. Villagers living on small outer islands in Tuvalu or behind rugged mountain ranges in PNG will never have access to grid-connected power. Moreover, even in areas where the terrain is favorable, the

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6/ Since resources required for micro-hydros are abundant in only a few Pacific Island countries, micro-hydros will not be discussed in this paper.

dispersion of population is such to preclude an economic connection in many cases: line losses increase with increased length of the line and lower voltage of transmission, while the initial cost of the line increases dramatically with transmission voltage. (For example, whereas the cost of an 11 kV and a 22 kV line are fairly close per km, the cost of a 33 kV line per km is often double the cost of a 22 kV line.) Rural electrification projects serving areas of low demand density cannot justify the cost and severe under loading of a high-voltage transmission line. However, the feasible length of 11 kV and 22-kV lines is strictly limited, usually to under 100 km, by what are considered to be "tolerable" line losses.

Except in cases where rural electrification by the urban power utility is subsidized, power utilities will not extend transmission to a new area until existing or potential demand on the new system exceeds some threshold which makes the project commercially viable, since initial costs are high (averaging about US$12,000 per km in the Pacific Islands region). Although calculations differ from power utility to power utility, the PNG Electricity Commission developed a criterion of a minimum of 5 kW of average demand per km of 11-kV transmission line in the mid-1980s as a rough rule of thumb for rural transmission extension projects 7/. Most transmission line extensions in PNG longer than 5 - 10 km for electrification of villages would not meet this criterion.

Capital Costs

Because topographical conditions vary so widely among the Pacific Islands countries, it is difficult to generalize about the costs of constructing transmission lines; some are constructed through mountainous terrain, others in coastal areas are often placed underground. Costs depend also on the availability of suitable local timber for poles. For these reasons, costs vary widely (for 11-kV lines, between about US$7,000/km through flat, open ground, to more than US$15,000/km through the highland bush in rural PNG). An average of US$12,000/km has been used for the regional economic analysis below.

Costs and Benefits of Stand-Alone Diesel Generators

To provide reticulated AC power to consumers in isolated areas that are beyond the reach of a transmission line from the urban grid, small diesel stations are often used (or, to a much less extent, micro-hydros where resources are suitable). Small diesel engine/generators have the advantages of relatively low initial cost with minimal civil works requirements (shed and concrete slab), compactness of design and ability to be transported to remote areas, availability in a wide range of sizes (machines 1 kW to, and reasonably long service life (>15 years) if well maintained and operated in a noncorrosive environment (away from the sea)).

Diesel technology, used widely in the region since the Second World War, is familiar to Pacific Islanders, if not well understood. For urban power supply in small countries such as

7/ It is not known whether this "rule of thumb" was ever adopted as official policy or whether it is still in use. It is quoted only as an indicative value and to show the functional relationship between "commercially viable load" and length of transmission lines. The actual value depends on local terrain conditions and construction and generating costs and may vary substantially even within the territory of a single power utility; the value that other power utilities in the region have adopted or may adopt is not known.

Kiribati, Tuvalu, and Tonga, diesels are the only practical technology currently available 8/. Although diesels require a constant input of imported fuel and spare parts, coupled with considerable technical expertise to maintain them, most countries which must rely on diesel power for their urban grids have managed to organize the necessary resources to keep them operating, a task which has been made possible because urban centers have good connections with overseas markets, technical expertise is available or can be brought in from overseas, and the income levels of urban consumers are high enough to support at least the operating costs.

However, diesels have not provided a practical and effective means of rural electrification in most countries that have tried them, even though rural diesel stations are common in some countries (e.g., Fiji, PNG, and the Cook Islands; less common but still present in the Solomon Islands, Kiribati, Tonga, Western Samoa, and Vanuatu). As mentioned previously, rural areas are more difficult to access, have less (usually no) skilled manpower, and have lower household income levels than urban areas; as a result, fuel and spare parts are more costly, maintenance of equipment is poorer, and recovery of operating costs from local revenues is much less (close to zero in some countries). To cite an extreme example, the economic cost of fuel delivered to Woitape (a small diesel powered government station with no road access, half an hour flight from Port Moresby) in the Central Province of PNG is three times the cost of the fuel in Port Moresby. Consumers in Woitape are not metered, and no revenues are collected. The station is supposed to operate 6 hours/day to provide power for lighting, refrigeration, and entertainment to the district office, a Department of Primary Industries research station, a dozen or so government quarters, an unknown but small number of non government bush-material houses and tradestores, a religious mission, and an expatriate-owned guest house, but is often broken down. When a breakdown occurs, a technician from the PNG Electricity Commission in Port Moresby is flown in to diagnose the problem followed by a return visit with spare parts; repair procedures usually take a month or more. Consequently, consumers who could afford to buy small generators of their own (i.e., the guest house and the religious mission) have done so, while the rest of the consumers frequently go without power for long periods 9/. This experience has been repeated in many isolated diesel stations in PNG and (to a lesser degree) in Fiji and other countries.

In general, it is fair to say that rural diesel stations in Pacific Island countries provide power at an economic cost (US$1/kWh, even US$2/kWh in some cases) that is higher than can be justified by the low quality of power that they produce. For a national power utility, full cost recovery from revenue collected in small isolated diesel stations is usually not possible, because charging the required tariff would probably choke off demand almost entirely even if national tariff

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8/ These countries and others in the region lack hydro resources. Other options for urban power supply include gas turbines, steam turbines using biomass, heavy oil, coal, or geothermal energy, OTEC and wavepower. To date, only hydro is used as a substitute for diesel power in the region's urban grids, and only in four countries (PNG, Fiji, FSM, and Western Samoa). Gas turbines were used heavily in PNG in the late 1970s and early 1980s but have been discontinued due to high costs and low reliability. Except for the heavy-oil steam turbines built to supply the Bougainville copper mine (now shut down) and the adjacent towns of Arawa and Kieta in PNG, the other technologies have not been used in urban power systems in the region at all, either because their costs are even higher than diesel or the indigenous resources on which they depend (biomass, seawave, or geothermal energy) are not available or have not yet been developed.

9/ A 60 kW micro-hydro scheme is now under construction in Woitape by the National Government to correct many of these problems. Woitape, however, is one of approximately 90 such stations in rural PNG, only few of which have hydro resources to be developed. PNG provides many of the "worst" examples of diesel-based rural electrification in the region because access problems to remote stations in PNG are the most difficult, owing to PNG's extremely rugged terrain. In contrast to other countries in the region, many of PNG's rural stations are accessible only by air.

policy allowed such a tariff to be charged. In practice, isolated diesel power systems throughout the region are subsidized, either directly through government grants or (more commonly) indirectly through cross-subsidy from urban electricity consumers.

Rural service institutions such as health centers, schools, and religious missions, and private enterprises such as guesthouses, tradestores, and plantations are usually exceptions to this generalization. Such organizations often possess their own "captive" diesel gensets because they need power for off-hours lighting and running specialist equipment, or because they need more reliable power than the available public power system can provide. Compared to government-owned diesel rural electrification schemes, captive gensets are usually much better maintained and run with higher reliability, because ample funds for maintenance are provided in the organizations budgets and there are likely to be trained staff available to operate them.

Capital Costs

An average cost of US$1,000/kW for small stand-alone diesel generators, including engine, generator, power house, and electrical equipment is used in the economic cost comparison below. Actual costs, however, depend strongly on the remoteness of the rural site to the urban area used for import and trans shipment of the equipment. The above cost per kW does not include the distribution system or customer connections, which will vary according to the number and the dispersal of population around the station, and the topography. (Costs for distribution and customer connections in the comparison below were excerpted from an early 1990 study of actual costs in Kiribati (Tarawa).

Photovoltaics

Household photovoltaic systems are capable of a limited power output and are appropriate for isolated villages where load is mainly or solely domestic. Perhaps the most distinguishing feature of household photovoltaics, economically speaking, is that they are not subject to economy of scale. PV units (typically, two panels, a controller, one or two batteries, and household fixtures) are capable of a fixed output; the only way to double the output is to double the equipment for collecting and storing energy, but the per-unit costs remain the same. In contrast, other power generating technologies like diesel and hydro are subject to economies of scale, meaning that per-unit costs go down as capacity increases. For areas where power requirements are very small, therefore, photovoltaics are appropriate because fixed costs are low, but they increase linearly as requirements for power increase. When load increases beyond a certain size (either through an increase in the number of customers, or an increase in usage per customer, or both), then photovoltaics are no longer the least-cost method of supply, and a conventional central-station technology with economy of scale becomes more appropriate. This is illustrated in the case study below, comparing the costs of grid extension, stand-alone diesel, and photovoltaic options for electrification of North Tarawa (Kiribati).

Capital Costs

The main capital cost in a household photovoltaic system are the solar energy-collecting panels, which are initially the most expensive component, and the batter(ies) which need to be replaced every four or five years (or more frequently without proper maintenance). The technology in the panels is still evolving, and recent small reductions in the per-unit cost of solar panels have been possible. (The technology in batteries, however, is well developed and significant cost breakthroughs are not in sight). The initial cost of household PV systems is gradually downward.

Based on costs of systems installed in the region in 1988 10/, a household PV system capable of powering 2x20 watt fluorescent lighting tubes for four hours/day and one power point for a radio or other small-wattage device is on the order of US$1,100, consisting of two panels at US$350 each, one battery at US$150, one controller at US$175, and wiring at US$90.

Case Study of Comparative Costs: Electrification of North Tarawa (Kiribati)

A recent study of the costs of electrification of North Tarawa in Kiribati, between the villages of Nabeina and Buariki (see map) is provided by the Asian Development Bank 11/. Although the study did not consider photovoltaics as an option for North Tarawa, it does provide a detailed analysis comparing the costs of an extension of the South Tarawa grid to the northern-most village of Buariki and the villages in between to the costs of constructing and operating a stand-alone diesel station in each village. The costs for the "grid extension" and "stand-alone diesel" options in the economic comparison in the following tables are excerpted from that study. The costs for PVs were derived from 1988 project costs (see the reference in footnote 10) and from a 1990 tender for an EEC-funded household and meeting house PV project 12/.

The cost comparison below is an economic one, that is, it compares the overall resource cost of each electrification option, including the initial cost of power generating and distribution equipment, maintenance and fuel costs (where applicable) and household costs including wiring and the purchase of electrical appliances. No attempt is made to allocate the costs between consumers and suppliers.

The period of the comparison is ten years, and it is assumed that all equipment - power equipment, household appliances, etc., is purchased at the start of the period (1991) and is replaced as necessary according to the useful life of each item. The major assumptions underlying the comparison (such as fuel prices, equipment costs, discount rate, etc.) are listed in Table 1 and the resulting cash flows are shown in Table 2.

The cash flows were calculated using the Lotus 1-2-3 computer program, so that changing any assumption to measure the effect of the change, such as the number of households served under each option, is very easy. The data in the ADB study show that the potential household electricity market in North Tarawa comprises some 250 households. The cost analysis in Table 2 shows that photovoltaic would be the marginally least-cost method (in present value terms, only slightly less costly than using stand-alone diesels) of serving that many customers under the appliance and other assumptions that are listed in Table 1. However, if the number of electrified households is increased to 500 or more, then stand-alone diesels become the least-cost option (see the graph following Table 2). At 1,000 households, the present value of costs for photovoltaic exceeds that of the grid extension option. However, the grid extension is never the

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10/ See PEDP Report REG 88-8, A Simple Lotus 1-2-3 Template for Estimating Costs of Household Photovoltaic Lighting Systems, by Chris Harwood.

11/ Asian Development Bank TA1070-KIR, Kiribati, Report on Future Power System Expansion, KRTA Consultants Ltd in association with Coopers & Lybrand (NZ), March 1990.

12/ Kindly provided by Frans Feil, EEC consultant to the Forum Secretariat.

least-cost option due to high fixed costs resulting from the distance between Nabeina-Buariki and South Tarawa (roughly 20 - 60 km) and the small load in the project area. On the other hand, if the number of households in the market is reduced to 200 or less, photovoltaic is the least-cost option, to a more marked degree as the number of households gets smaller.

Table 1

Case Study of Grid Extension vs Stand-Alone Diesels vs Photovoltaics for electrification of North Tarawa (Nabeina-Buariki, Kiribati)

ALL COSTS IN 1990 US DOLLARS

GENERAL ASSUMPTIONS

ADO fuel cost/litre:	$0.43	
Wiring cost per building:	$90.00	
Generation eff., grid	0.29	l/kWh
Generation eff., stand-alone	0.35	l/kWh
Transmission losses	15%	
Distribution losses	7%	
Number of electrified households Nabeina-Buariki:	250	
Total number of villages:	10	
Average hhs per village:	25	
Real discount rate:	10.0%	

APPLIANCES USED

	Wattage	Cost	Life (yrs)	Hrs/day operated by .. Households	Community Halls
DC refrigerator 1/	85	$1,875	20		6
AC refrigerator 2/	400	$950	20		6
Radio	40	$50	10	12	
Iron 3/	1000	$60	15	1	
Fluorescent light	20	$5	3	4	6
Video	100	$2,500	10		3

1/ used only with PV system
2/ used with either grid extension or stand-alone diesel system
3/ used only with grid extension system

MAINTENANCE

GRID EXTENSIONS

Annual expenditure, % of capital cost	1.0%

STAND-ALONE DIESELS

Maintenance, inclusive of periodic major overhauls of engines/generators, US dollars/kWh	0.10

PHOTOVOLTAICS

Annual expenditure, % of capital cost:

Panels	0.5%
Batteries	5.0%
Controllers	7.0%

POWER SYSTEM CAPITAL COSTS

STAND-ALONE DIESEL AND GRID EXTENSION COSTS TAKEN FROM 1990 KRTA STUDY OF ELECTRIFICATION OF NORTH TARAWA

PV EQUIPMENT

		Cost	Life (yrs)
Panels	53Wp	$350	10
Batteries	100Ah	$150	4
Controllers		$175	5

Number required per ...	Household	Community Hall
Panels	2	10
Batteries	1	4
Controllers	1	2

CONSUMPTION OF ELECTRICITY (MWh PER YEAR)

		Comments
GRID EXTENSION		
Households	89	electric irons owned by 1/3 of electrified households, used 1 hour/day
Community Halls	12	50 litre AC refrigerators used
Total	101	
STAND-ALONE DIESELS		
Households	58	no electric ironing
Community Halls	12	50 litre AC refrigerators used
Total	70	
PHOTOVOLTAICS		
Households	58	no electric ironing
Community Halls	5	high-efficiency 50 litre DC refrigerators used
Total	64	

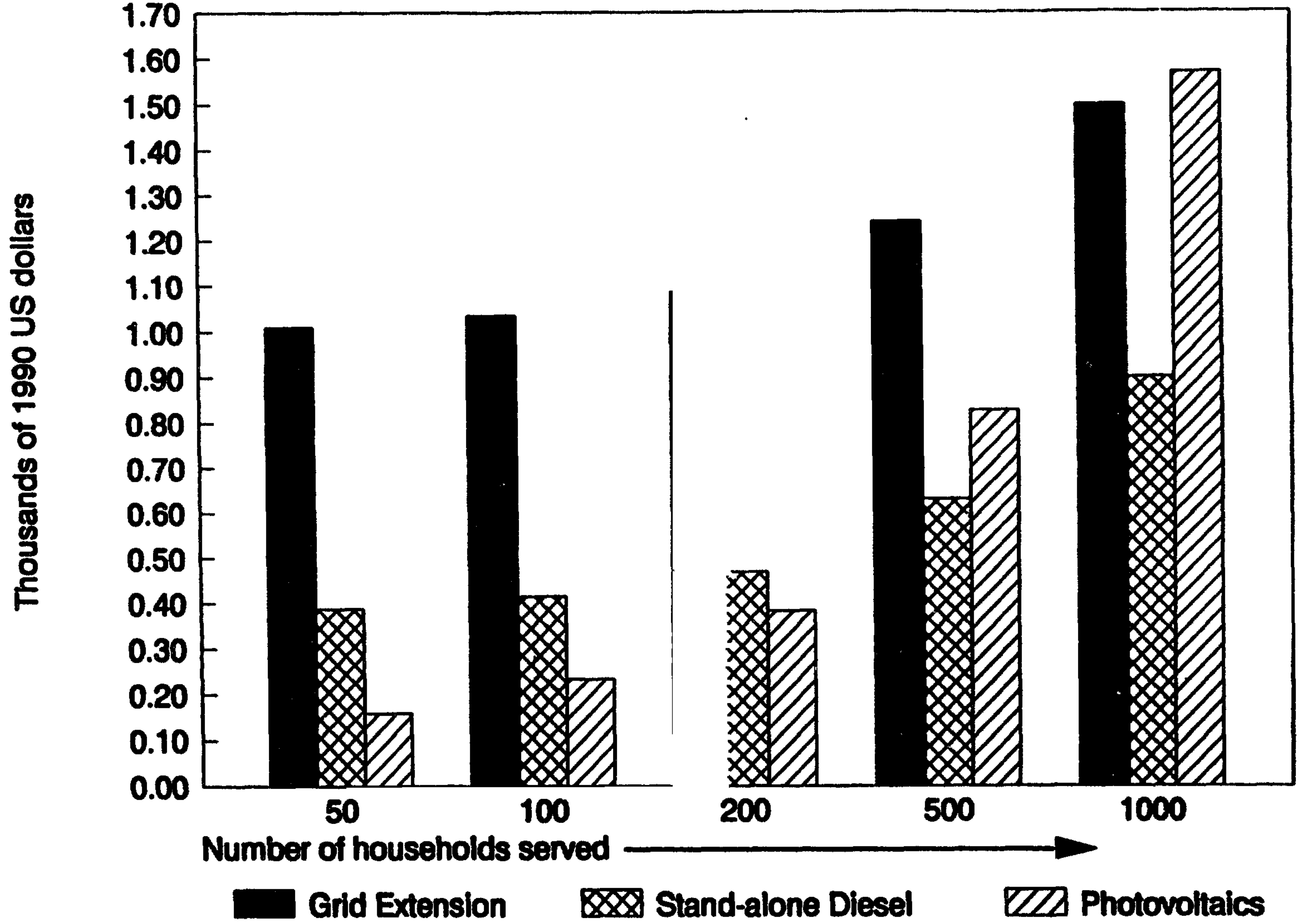
Table 2

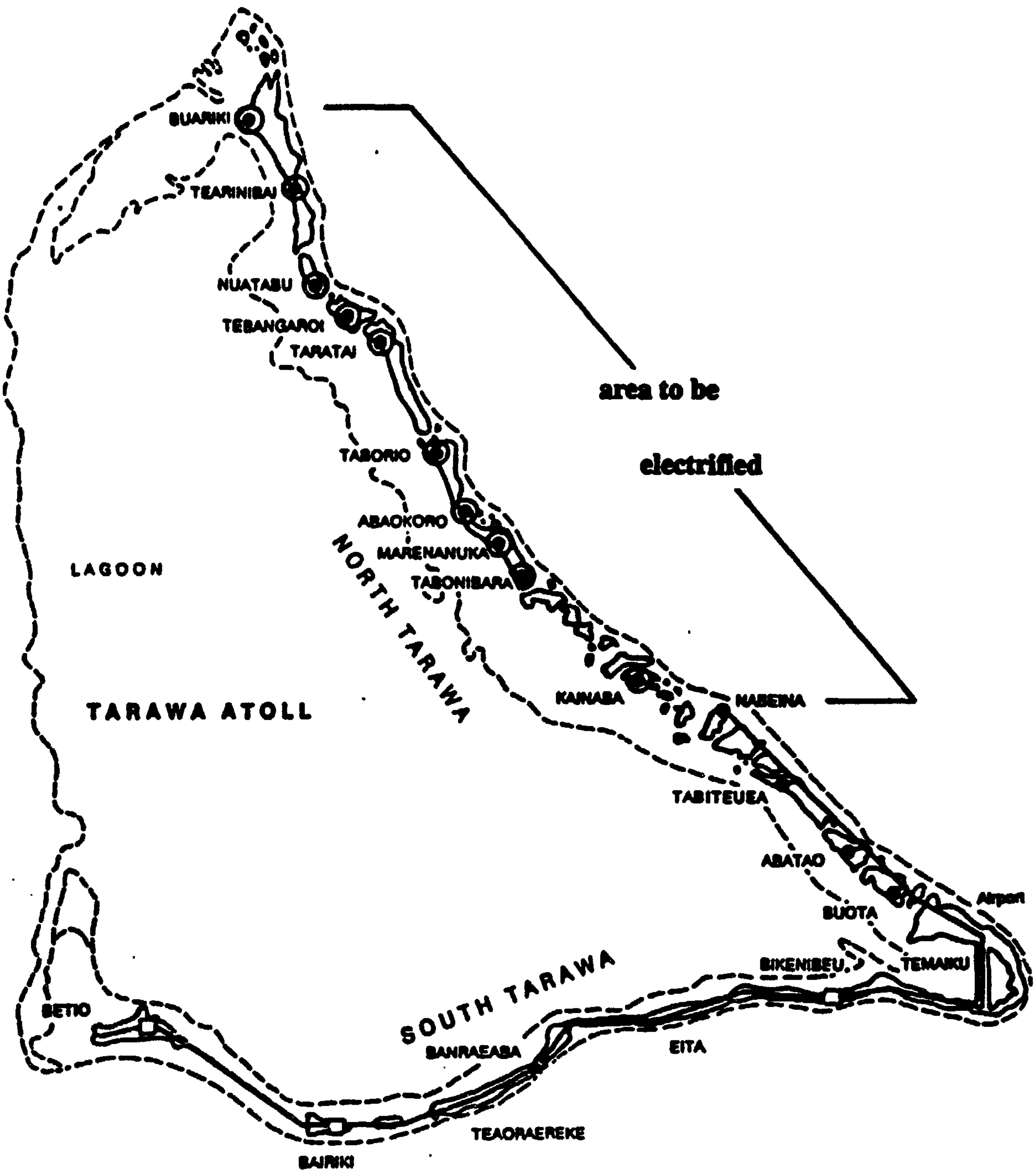
ECONOMIC COSTS (US DOLLARS '000)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GRID EXTENSION										
Capital Costs										
Transmission	590	197								
Distribution		227								
House & community hall writing		23								
Household equipment:										
2x20 watt fluor lights	3	0	0	3	0	0	3	0	0	3
Radios	13	0	0	0	0	0	0	0	0	0
Electric irons	15	0	0	0	0	0	0	0	0	0
Communal equipment:										
5x20 watt fluor lights	0.25	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.25
Refrigerators	10	0	0	0	0	0	0	0	0	0
Videos	25	0	0	0	0	0	0	0	0	0
Operating Costs										
Electricity required (MWh)	116	116	116	116	116	116	116	116	116	116
ADO fuel ('000 litres)	34	34	34	34	34	34	34	34	34	34
Fuel cost	15	15	15	15	15	15	15	15	15	15
Transmission line maintenance	0	10	10	10	10	10	10	10	10	10
Total costs	669	472	25	27	25	25	27	25	25	27
Present value of total costs	1,113									
STAND-ALONE DIESELS										
Capital Costs										
Power stations	112									
Distribution	227									
House & community hall wiring	23									
Household equipment:										
2x20 watt fluor lights	3	0	0	3	0	0	3	0	0	3
Radios	13	0	0	0	0	0	0	0	0	0
Communal equipment:										
5x20 watt fluor lights	0.25	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.25
Refrigerators	10	0	0	0	0	0	0	0	0	0
Videos	25	0	0	0	0	0	0	0	0	0
Operating Costs										
Electricity required (MWh)	75	75	75	75	75	75	75	75	75	75
ADO fuel ('000 litres)	26	26	26	26	26	26	26	26	26	26
Fuel cost	11	11	11	11	11	11	11	11	11	11
Diesel station maintenance	8	8	8	8	8	8	8	8	8	8
Total costs	431	19	19	22	19	19	22	19	19	22
Present value of total costs	498									
PHOTOVOLTAICS										
Capital Costs										
Household equipment:										
2x20 watt fluor lights	3	0	0	3	0	0	3	0	0	3
Radios	13	0	0	0	0	0	0	0	0	0
PV panels	175	0	0	0	0	0	0	0	0	0
Controllers	44	0	0	0	0	44	0	0	0	0
Batteries	38	0	0	0	38	0	0	0	38	0
House & community hall wiring	23									
Communal equipment:										
5x20 watt fluor lights	0.25	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.25
Refrigerators	10	0	0	0	0	0	0	0	0	0
Videos	25	0	0	0	0	0	0	0	0	0
PV panels	35	0	0	0	0	0	0	0	0	0
Controllers	4	0	0	0	0	4	0	0	0	0
Batteries	6	0	0	0	6	0	0	0	6	0
Operating Costs										
System maintenance (cash cost)	7	7	7	7	7	7	7	7	7	7
Total costs	380	7	7	9	50	54	9	7	50	9
Present value of total costs	457									

Electrification of North Tarawa, Kiribati

A Comparison of the Present Value of Costs of 3 Alternatives





Kiribati

Tarawa Atoll

CASE STUDY ON THE FINANCIAL VIABILITY OF SOLAR WATER HEATERS ON A HOTEL TARAWA, KIRIBATI

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Introduction

Solar water heating is generally seen as the most economic means of providing hot water in the Pacific region. It is finding wide application both in developed and developing countries as a means of reducing and stabilizing the costs of providing this service, particularly within the domestic sector and within the hotel industry. This paper describes the process of determining the viability of solar water heating for a hotel complex located in Kiribati and shows that substantial savings in electricity cost can be achieved.

Background

The Otintaai Hotel is located on Tarawa in Kiribati. Until mid-1988, overseas guests were accommodated in a reasonably modern 20 room wing. Hot water was provided to each of the rooms and was heated using electric storage water heaters, many of which were deteriorating and would soon require replacement. The cost of electricity to commercial users on Tarawa at that time was A$0.38 per kwh and it was suggested, by the Ministry of Works and Energy's Energy Planning Unit, that hotel water heating costs might be reduced significantly with the installation of a number of solar water heating systems. Following discussions between hotel management and the Energy Unit, it was agreed to examine the suggestion. At that time, work was proceeding with the refurbishment of the hotel in for the meeting of the Forum Heads of Government in June 1988. The refurbishment programme included the demolition of an old portion of the hotel and construction of a new 20 room wing together with extensive renovation to an existing 20 room wing. Specification of the new wing included the installation of solar water heaters which would provide hot water to each guest room. Discussion were also held with the Chief Engineer of the Public Works Department who was responsible for renovation and it was agreed that the Department would assume responsibility for installation of the systems if the proposal proved to be justified. Through the Ministry of Works and Energy, funding for such a project was available through the Small Energy Projects Programme administered by the Forum Secretariat. It appeared, therefore, to be an ideal opportunity to initiate a detailed project proposal.

Feasibility Assessment

This assessment was aimed at determining the present cost of providing hot water and to compare that cost with the cost of providing the same service using solar water heaters. To do this, a number of parameters needed to be determined.

Determination of Annual Water Heating Costs

Daily Hot Water Needs:

It was necessary firstly to estimate the daily hot water volume (Q_{daily}) required per person. A bucket, a soft drink bottle of known volume (V_{btls}) and a digital watch was used. A normal shower (usual pressure and temperature) was set running in one of the hotel rooms, the cold water tap turned off and the time taken to fill the bucket (Tm_{buck}) from the shower was measured. As the volume of the bucket was unknown, the number of full soft drink bottles (N_{btls}) necessary to fill the bucket was counted.

The flowrate (Q_{shr}) of the hot water used for a shower was then determined using the equation:

$$Q_{shr}(lts/sec) = N_{btls} \text{ X } V_{btls}(lts) \ / \ Tm_{buck}(secs)$$

It was assumed that in Tarawa (hot and humid) most guests would shower twice daily (N_{shr}) for an average shower time (Tm_{shr}) of 5 minutes. An additional volume of 4 liters per day (Q_{add}) was assumed for shaving, hand washing, etc. A volume was assumed for these functions. The total volume of hot water used per person per day was therefore determined for the following equation:

$$Q_{daily}(lts/pers/day) = Q_{shr}(lts/sec) \times N_{shr}(shrs/day) \times Tm_{shr}(mins/shr) + Q_{add}(itrs/day)$$

Hot Water Storage Temperature:

The temperature of the hot water (T_{hot}) and cold water (T_{cold}) being supplied to the shower was determined by shutting off the hot and cold water taps in turn and taking the reading with the thermometer. A temperature difference, due to thermal losses in the connecting pipes between the hot water heater and the shower outlet, of 5°C was assumed. In many installations this could be considerably greater, particularly if hot water piping is not insulated (lagged) so this assumption it likely to be conservative. The temperature of the hot water in the storage tank was thus estimated using:

$$T_{heater}(°C) = T_{shr}(°C) + 5°C$$

Annual Hot Water Consumption

To estimate the total amount of water used by hotel guests over a year, it was necessary to look into the hotel records to determine the hotel occupancy rate (O_{annual}) and the number of people usually occupying each room. The occupancy rate is a measure of hotel utilization, indicating the amount of time (number of days) guest rooms were occupied over a full year. It was calculated by determining the number of days each room was occupied and summing these values for each of the 20 rooms to give a total number of room days per year of occupancy. This figure was then divided by the total number of room days available per year (i.e. number of rooms (N_{rms}) x 365 days per year or 7,300 room days per year).

In addition, it was necessary to determine the usual number of people occupying each room to more accurately determine hot water requirements. This however would have involved considerable extra work as hotel records did not specifically show this. A conservative assumption was therefore made that only one person occupied each room at a time with the result that actual hot water consumption is likely to be underestimated.

A total hot water volume required per year (Q_{annual}) was then calculated as follows:

$$Q_{annual}\ (lts/yr) = Q_{daily}\ (lts/rm/day) \times O_{annual}\ (room\ days) \times N_{rms} \times 365\ (days/yr)$$

Using published data 1/, the Specific heat of water (H_{water}) (i.e. the energy required to raise one litre (or one kg) 2/ of water through one degree celsius) was determined. Together with the temperature through which the water needed to be heated (T_{heater} - T_{cold}) and annual volume of hot water required Q_{annual}, the energy required to heat the water (P_{heat}) was determined from:

$$P_{heat}(MJ/yr) = H_{water}(KJ/kg/°C) \times O_{annual}(lts/yr) \times (T_{heater} - T_{cold})°C\ /\ 1000\ (KJ/MJ)$$

Dividing by the standard conversion factor of 3.6 MJ/kwh and multiplying by the cost of electricity, the annual cost to heat the necessary volume of water was determined.

Determination of hot water storage costs:

Water stored in the tanks was maintained at a preset temperature as it was the practice of the hotel to maintain a ready supply for each of the rooms, even if the room was not occupied. This practice obviously had a cost in electricity required to keep the water at the desired temperature. As the tanks were not perfectly insulated, heat was lost from the tanks surface.

To determine this cost, it was therefore necessary to estimate the heat loss from the storage tanks. To do this, the thickness of the insulation (W_{insul}) and type of insulation was checked on the tanks themselves with the surface area of the storage tanks (S_{tank}) calculated from physical measurements of tanks diameter and height.

Again, using published data to find the heat transfer coefficient (U_{insul}) (i.e. the energy lost from a unit area of tank surface for a known thickness of insulation for a temperature difference across the insulation of one degree). This was determined for the type of insulation used. Using an assumed average temperature difference of the water in the tank (T_{heater}) and the surrounding atmosphere (T_{atmos}), the following equation was used to estimate the energy (P_{store}) lost from the surface of all storage tanks and hence the amount of energy required to maintain the hot water at the required supply temperature:

$$P_{store}\ (W) = U_{insul}\ (W/m^2/°C) \times S_{tank}\ (m^2) \times (T_{heater} - T_{atmos})\ (°C) \times N_{tanks}$$

The total amount of electricity required per year is calculated by:

$$E_{store}\ (kWh/yr) = P_{store}\ (W) \times 24\ (hrs/day) \times 365\ (days/yr)\ /\ 1000\ (W/kW)$$

Again, the cost of providing this electricity is determined using the current price of electricity.

1/ CRC Handbook of Physics and Chemistry (CRC Prem 1981)

2/ 1.0 liter of water weighs 1.0 kg

Summary of Calculations:

Using the methods and equations described above, the cost of providing hot water to the hotel guest rooms was estimated. Table 1 shows the results of these calculations.

Capital Cost of Solar Water Heaters

It was then necessary to determine the costs of installation of solar water system at the hotel. Information was sought from the architects who designed the new wing of the hotel and had specified the size and number of solar water heaters to be installed. They indicated that five 300 litre capacity systems would be necessary.

A quotation was then requested from a manufacturer in Australia for the C.I.F. supply of 6 solar water heaters, 5 to be installed to satisfy demand in the old guest wing and one to be installed, at the suggestion of the hotel management, to assist in meeting kitchen hot water requirements. Differences in crating, freight and insurance costs between the supply of between 5 and 6 systems were expected to be minimal. Quoted prices are detailed in Table 2 below.

Installation Costs:

The units were installed by the Public Works Department in Kiribati. The costs associated with installation customs clearance, internal transport, labor costs, etc.) were not specifically determined. Installation was subsequently included in already planned renovations of the old guest wing. An estimate of $500 is used in this analysis.

Recurrent Costs:

It was assumed, for the purpose of this initial assessment, that recurrent costs (repairs and maintenance) for either the existing electric storage heaters and a solar water heating system would be about the same. Therefore recurrent expenses could be ignored in this analysis.

Salvage Value:

It was thought that the existing electric hot water tanks would be discarded. Salvage value was therefore assumed to be zero.

Table 1: Estimate of Hot Water Supply Costs - Otintaai Hotel

Cold Water Temperature (T_{cold}) °C	30
Hot Water Temperature (T_{hot}) °C	70
Atmospheric Temperature (T_{atmos}) °C	30
Average Shower Time minutes	5
Number of Showers Per Day	2
Electricity Cost $/kwh	0.38
Number of Rooms (N_{rms})	20
Number of Hot Water Storage Tanks (N_{tanks})	5
Insulation Material	glass wool
Insulation Thickness mm	25
Specific Heat of Water (H_{water}) KJ/KG/°C	4.2
Heat Transfer Coefficient of Insulation (U_{insul}) W/M2/°C (25mm thickness with 1.0,F temperature difference)	0.914
Water Heating Costs	
Hot Water Flowrate (Q_{shr}) lts/sec	0.02
Estimated Storage Temperature (T_{heater}) °C	75
Hot Water showers) lts/room/day	12.0
Hot Water Sundries) lts/room/day	4
Total Hot Water requirement (Q_{daily}) lts/room/day	16.0
Hotel Occupancy Rate (O_{annual})	59.8%
Total Hot Water requirement (O_{annual}) kls/year	70.08
Energy Required for Water Heating (P_{heat}) Mj/year	13245
Equivalent Electricity Requirement kWh/year	3679
Estimated Annual Hot Water Heating Costs	1,398
Hot Water Storage Costs	
Storage Tank Surface Area (S_{tank}) M^2	1.95
Estimated Heat Loss from Water Storage Tanks (P_{store}) W	722
Equivalent Electricity Requirement (Ftoe) kwh/year	6,325
Estimated Annual Hot Water Storage Cost	$2,403
Total Estimated Hot Water Supply Costs	$3,801

Table 2: Equipment Capital Costs
(1988 Australian dollars)

Description	Quantity	Unit Price	Total
Solar Water Systems Complete with all fittings and 1.8 kW element	5	1,132	5,660.00
Heavy duty crate for tanks	1		347.50
Heavy duty crate for panels	1		213.00
Total Ex-factory			6,220.50
Insurance			60.00
Freight			1,632.00
Total C.I.F. Tarawa			7,912.50

Total Cost of Project A$8,412

Project Evaluation

Now, comparing the estimated costs for replacing the existing hot water tanks with solar water heaters ($8,412) with the expected cost savings accrued through the displacement of electricity by solar ($3,800 3/ per year), it can be seen that the cost of the solar water systems would be recovered from savings in electricity in a little over two years (i.e. $8,412/$3,800) based on the above conservative estimates. As the useful operating life of the solar systems is expected to be around 10 years, net savings in electricity consumption accruing to the hotel will obviously be significant.

Using an interest rate of 10% per year over the expected operating life of the solar systems of 10 years, the present value of the project was determined from the following equation 4/.

$$\text{Present value} = \frac{1 - (1 + \text{interest rate})^{-\text{life}}}{\text{interest rate}} \times \text{Savings} - \text{Project cost}$$

using:

interest rate	10%
life	10 years
Project cost	$8,412
Savings	$3,800

calculating:

Present value	$14,937
or	$1,494 per year

3/ Assumes that electric boosters (requested by the hotel) are not connected.

4/ In Lotus 1.2.3 the equation to calculate the present value of the project is @PV(3800,0.1,10)-8412.

On this basis, the hotel decided to go ahead and install the solar heaters in time for the Forum meeting.

There are obviously other areas where solar hot water heaters can be used within the hotel. As mentioned, the hotel subsequently decided to use a solar water heater to provide hot water for the hotel kitchen. Hospitals and dispensaries also, with their requirement for a continuous supply of hot water, are another ideal location for utilization of solar water heaters.

IX. ISSUES IN PLANNING AND MANAGING HOUSEHOLD AND RURAL ENERGY

IMPLICATIONS OF URBAN AND PERI-URBAN HOUSEHOLD ELECTRICITY DEMAND GROWTH

Gerald Foley
Consultant

Urban and peri-urban household electricity demand is growing strongly in most Third World countries. This is posing severe problems for many electricity supply utilities, but is rarely considered as a priority in discussions on energy policy and development assistance funding.

There are, however, strong technical, economic and social reasons for devoting considerably more attention, and resources, to urban domestic electrification programmes.

State of Urban Electrification Systems

The proportion of urban families with an electricity supply varies widely across the developing world. In the more prosperous countries, it is normal for 80-90% of urban families to be connected. But in countries at a lower economic level, such as, for example, those in Sub-Saharan Africa, the proportion of families with a supply is likely to be in the range 5-10%.

In many cases, potential urban consumers face long delays in obtaining connections because utilities lack the resources required for expansion of their distribution systems. The common phenomenon of electricity theft by means of illicit connections is not just a way of obtaining a supply for nothing; it also enables people to avoid the interminable wait for an official connection which they would otherwise have to endure.

The lack of resources for proper operation and maintenance of urban supply systems means that many are in a deplorable condition. Supply networks are so overloaded in some places that voltage drops of 50% are being experienced; and system losses may be as high as 40%. Administration may also be extremely ineffectual with utilities suffering major financial losses as a result of delays in issuing and collecting bills.

A large part of the reasons for such problems is that tariffs are set at a level which does not cover production and distribution costs. Governments, at the same time, are usually unwilling to make up the full shortfall in utility finances. The result is that many do not have the resources to maintain their generating plant and supply networks in a satisfactory manner.

Under these conditions, utilities are normally reluctant to compound their problems by extending their supply networks. Political pressures, however, tend to overrule engineering judgments and networks have to be expanded despite the fact that there are not sufficient funds to provide the strengthening and upgrading of the network required if it is to continue functioning properly. The technical consequences in terms of increased unreliability and higher system losses are quickly apparent. Less obvious, but ultimately perhaps more serious, is that the continual pressure to violate the standards of good electrical engineering practice tends to have a debilitating effect on the morale and performance of the technical staff who are vital to the effective running of the utility.

A further factor contributing to the poor state of urban supply systems is the tendency for donor funding to be concentrated upon expansion of supply capacity. Projects for the construction of power stations and transmission grids possess the merit, from the viewpoint of funders, that they have high material and technical assistance components and hence are easy to provide under tied aid programmes. The lower material content and relatively minor technical demands of strengthening or extending the urban reticulation mean there is much less scope for donor country manufactures or engineering skills.

The tendency to focus upon expansion of the supply is reinforced by the design methodology used in many cases. This places a high economic cost, sometimes greater than $1.0 per kWh, on projections of unmet electricity demand. Since such calculations tend to provide an apparently excellent rate of return on virtually any supply expansion project, there is little pressure to look at how much more cost effective the same investment in rehabilitation of the existing power stations or urban distribution network would be. The end result is that, in many countries, new power station capacity is continually being grafted into electricity systems which are fundamentally unhealthy in both a technical and financial sense.

<u>Merits of Rehabilitation and Expansion of Urban Supply Systems</u>

Rehabilitation of urban electricity supply systems offers some of the most cost-effective options in the whole electricity investment area. Since petroleum fuels are used for the bulk of the Third World's electricity generation, the rise in petroleum prices - for however long it lasts - adds to the attractiveness of such rehabilitation projects.

The improvements obtainable from the rehabilitation of an urban supply system can be quite dramatic as is illustrated by the following arbitrary, but by no means extreme, example. Suppose a poorly maintained power station has an output efficiency of 18% and the distribution losses are 30%. This means that for every 100 kWh of fuel used in the power station, the consumers receive 12.5 kWh. If the efficiency of the power station is raised to 30% and the losses are reduced to 15%, the same fuel-use in the power station will mean the consumers receive 25 kWh. The result will be a doubling of the energy efficiency of the system and a halving of the fuel cost per unit of electricity delivered.

The effect is to improve the financial position of the utility. It also strengthens the network thereby providing a firm basis for future expansion. In contrast, providing new supply capacity would increase the system losses as well as burdening the utility with greater plant operation and maintenance responsibilities.

Expansion of the urban supply system also shows up favorably when compared with rural electrification. The density of consumers in the urban areas means that the costs of reticulation are much lower than those involved in providing small numbers of connections in rural communities. The costs of maintenance, repairs, issuing bills and dealing with defaulters are also very much lower than they are in the rural areas.

The Question of Tariffs

It is, however, vitally important that urban electrification programmes are not seen purely in technical terms. The question of tariffs is crucial. Utilities must have the financial resources required to operate effectively, maintain their plant and equipment, and pay the wages necessary to retain their skilled technical and managerial staff.

The main source of such funding is the revenue they obtain from their customers. Governments have so many calls upon their limited resources that they cannot be expected to run the electricity utility as a social service. Neither is there any reason why they should. Experience in the industrial world shows that properly run utilities, which are allowed to set their own tariffs, can consistently run at a profit while providing a reliable and satisfactory electricity supply.

Many of today's tariff systems are not only too low to provide the utility with a profit on its investment, they do not even allow it to cover its basic fuel and operating costs. Another consequence of the low prices charged is that electricity demand is higher than it would otherwise be, thus compounding the technical and administrative problems of the utility. The end result is a greatly lowered level of service, higher fuel and running costs because of operating inefficiencies and overloading, and the exposure of the government to an open-ended subsidy to keep the utility running. Failure to set an adequate level of tariffs turns out to be totally counterproductive for the utility, the consumers and the government.

There is nothing iniquitous about charging a reasonable price for electricity. It is not a basic necessity of life like food or water. People with an electricity supply have immense discretion on how much they consume. Moreover, electricity is extremely valuable and brings quite enormous benefits to those who use it.

Lighting is the most notable of these benefits. Electric light transforms the interior of a house or small business. It opens possibilities for work, study and leisure which otherwise do not exist. In energy terms, a fluorescent tube provides light with an efficiency 400-600 times greater than a wick lamp. A household which uses a 60 watt bulb every night for four hours, provides itself with twenty times as much light as if were using a kerosene wick lamp. Its electricity consumption is just over seven kWh per month.

Electric appliances and small hand tools provide energy in a form which is unmatched in its versatility and flexibility. A small 0.5 kW electric tool has a work output in an hour equal to that of a full day's heavy manual labor. The owner of a shop or bar can transform its ambience and business potential by installing lights, a refrigerator, and a television set: the energy outlay required to run them is just a few kWh per evening.

Such benefits would still make electricity attractive at charges of 30-40 US cents per kWh. There is ample historical precedent for such charges; consumers in the industrial countries during the 1920s were paying the equivalent of $2-3 per kWh in today's prices. At present, there are charges of over 30 US cents per kWh being made in a number of developing countries, particularly where the supply is provided by private producers.

When looking at domestic and small business tariffs, it is not unreasonable to impose charges of up to 20 US cents per kWh where these are required to cover costs. Consumers will still obtain significant net benefits from their supply. Where lifeline tariffs are considered desirable to provide for the needs of poor consumers, the charge should still be at a reasonable level, say 10 US cents per KWh, and should be confined to a narrow band of perhaps 20 kWh per month. The deficit on this tariff should be made up by higher charges in the next band.

The aim in all cases should be to achieve a revenue flow for the utility which enables it to cover its fuel, maintenance, and repair costs and make an acceptable, if not necessarily fully commercial, return on its investment. By making it clear that the utility is responsible for the level of charges, the government would ensure that it was under public pressure to run itself as cheaply and efficiently as possible.

Electrification and Urban Development

Electrification is the key to modernity. Within the home it expands the potential for work and leisure in a dramatic way. A survey in Peru, for example, found that for women "having light at night enables them to sew, spin, knit, separate seeds etc, activities which only have been accomplished earlier with great effort under the light of a kerosene lamp or candle" (Valencia and Seppänen, 1987). The fact that electric light makes it easier for children to study is listed by families throughout the developing world as one of the major benefits of electrification.

Domestic appliances such as irons, kettles and hotplates help eliminate at least some of the drudgery of women's work. With the availability of refrigerators, food storage is improved and disease, particularly among children and infants may be reduced. A survey in Malaysia found that 72% of the respondents felt their health had improved because of refrigerated food and the greater ease in boiling water (Omar and Zin, 1988).

Extending the distribution system into urban and peri-urban areas which are at present without a supply automatically makes it available to businesses, small industries, and workshops. The vast majority of these will take a connection and the range of services available to the community will be increased. The World Bank, in a survey in Indonesia, for example, noted that a range of activities such as "beauty parlours, photocopying, ice making and battery charging" had come into existence after electrification (World Bank, 1986).

Although some of these are, in a sense, frivolous, they represent a progression above the basic struggle of subsistence living. They provide additional ways for people to dispose of their income and fulfil their aspirations for a better life. The expansion of the service sector is also a source of jobs for large numbers of people. In short, urban electrification is an integral part of the process of urban development upon which any increase in general living standards depends.

Urban Electrification and Fuelwood Consumption

While giving due acknowledgement to urban electrification for what it can do, it is important not to overstate the case by crediting it with what it cannot do. Otherwise distortions are likely to be introduced into the policy making process. It must therefore be recognized that urban electrification has little, if any, impact on urban fuelwood consumption, and still less upon the deforestation taking place in many Third World countries. The reasons for this are complex and are rooted in the dynamics of the fuelwood supply system and the broader changes in living patterns which come with urban living.

The majority of urban woodfuel supplies, whether as firewood or charcoal, are still obtained from natural woodlands or forests. There are few instances, apart from heavily subsidized forestry plantations or tree planting schemes funded by aid agencies, where trees are deliberately grown to provide fuel. The main reason for this is that fuelwood prices are almost invariably below those at which tree-growing for fuel is a profitable use of land.

Over the past two decades, there has been a great deal of alarm about the depletion of these woodfuel resources on which many of the cities in the developing world depend so heavily. At one stage it was widely believed that the depletion was caused by cutting trees for woodfuel. It is now generally accepted that clearing of land for agriculture is a far more potent cause of deforestation. This suggests that deforestation would continue even if woodfuel consumption were to cease completely; the only way to preserve forest resources is to control access to them.

It has also been found that woodfuel prices are not behaving as might be expected if resources were being depleted as rapidly as feared. Analysis of data from a wide variety of sources has shown that in many places price rises have not been taking place to any significant extent or can be tied more plausibly to factors other than resource depletion. The possibility that woodfuel resources are considerably greater than has been previously assumed is now being increasingly discussed in the energy literature and one project, funded by the Dutch government, is explicitly devoted to checking this hypothesis in the Sahelian region. 1/

The length of time for which woodfuel supplies are likely to be available at or around their present prices is thus a matter of some debate. But it is clear that at their present level, woodfuels are in most cases the cheapest available fuel option for urban families. The fact that they can be supplemented by gathered fuels adds to their attractiveness. They are also ideally suited to the traditional methods of cooking in large pots securely balanced on the three stones surrounding the fire.

As long as woodfuels remain available at their present relatively low costs, there is no economic reason for urban consumers to shift away from them. It is therefore unlikely that urban electrification will significantly cut into the present pattern of fuelwood consumption.

Electrification does, however, play a part in a more complex pattern of change in cooking habits which takes place with time in the urban areas. This can be seen happening in probably the majority of Third World towns and cities. On the urban periphery, geographically as well as economically, are newly-urbanized families who have retained an essentially rural way of living. Their houses are of traditional construction. Many still collect their fuelwood. They cook traditional dishes some of which may take hours of stirring and simmering on open fires. They use a kerosene wick lamp for lighting.

At the other extreme are those families which are fully integrated into urban living. They live in urban houses or apartments. Their diet is urban and includes a variety of processed or semi-processed foods; bread is one of the most common. Cooking the family meal is much quicker and much less of a central domestic activity. The fuels used are gas, kerosene or electricity.

1/ The project is being run by the Biomass Technology Group at Twente University in the Netherlands.

As the peripheral families become assimilated into the urban way of life, they gradually shift from their traditional diets and ways of cooking towards the characteristic urban pattern. The open fire has literally no place in a typical urban dwelling; neither is it necessary or suitable for preparing the typical urban meal. Irrespective of the relative economics of the different fuels, people therefore gradually shift away from woodfuels as they become more urbanized; some may, however, retain charcoal as a standby fuel or for the taste it gives to certain dishes.

Electricity as a cooking fuel tends to come late in this transition. Kerosene, because it does not require expensive appliances, is the natural fuel for people who are moving away from the use of woodfuels. Gas is generally more expensive and also requires a heavier investment in cookers and storage cylinders, but is still cheaper than wiring a house and paying for an electricity connection.

The shift to cooking by electricity, if it comes, is therefore likely to be away from kerosene or gas rather than fuelwood. The impact on fuelwood consumption of even a major urban electrification programme is therefore likely to be negligible; though it may ultimately have a noticeable effect on the consumption of gas or kerosene.

Role of Urban Electrification

Urban electrification cannot be seen as a direct means of easing the energy problems or alleviating the poverty of the urban poor. The cash barriers to obtaining a supply, paying for house wiring, purchasing appliances and keeping up with monthly bills make it inaccessible to the lowest income groups at which such programmes are aimed. This, in some measure, accounts for the lack of interest in urban electrification among most development assistance agencies.

Urban electrification has, however, its part to play in the general development and modernization of the urban areas. Without such economic development, there is no hope of improving the conditions of those at present surviving precariously, and as best they can, at the lowest levels of urban economic existence. Thus, although electrification has no immediate impact on the poorest in the urban areas, it is an essential to any longer term improvement in their economic prospects.

Urban electrification is also essential to the healthy development of electricity utilities and their prospects of extending supplies to the rural areas. Fully electrified urban areas provide an economic and infrastructural base from which rural electrification programmes can be launched. The existence of a strong urban consumer base also means that any cross-subsidy required for rural electrification can be widely spread and held down to an acceptable level, something which is not possible with today's sparsely electrified urban areas.

There are thus sound developmental, and economic reasons for devoting resources to the expansion of electricity supplies in the urban areas. Such programmes, however, have consistently failed to capture the imagination and interest of funding agencies - and of many developing country governments. And when they are launched, there is usually an attempt to justify them on the highly dubious grounds that they alleviate poverty or prevent deforestation.

Bias Against the Urban Areas

One of the reasons for the reluctance to commit funds to urban electrification is that there is a strong anti-urban feeling underlying a great deal of developmental thinking. Cities are frequently seen as parasitic upon the rural areas, agents of desertification and environmental destruction, and a major, though often ill-defined, threat because of their rapid population growth.

Thus, even when energy programmes are directly aimed at urban dwellers, as is the case with the majority of improved stove programmes, there is often an apology and a confession that they would have been carried out in the rural areas if it had been possible to make them work there. Rather than justifying them on the grounds that they enable rural households to make better use of their available woodfuel supplies, which they do, stove programmes tend to seek their rationale in their supposed effect on deforestation.

Indeed, there has been something of a crisis of confidence in the stove "movement" since it has become clear that the effect on deforestation of a major dissemination of improved stoves is likely to be very small. The fact these stoves provide real and tangible benefits to the urban families using them is felt to be, if not suspect, at least an inadequate reason for spending scarce development funds upon them.

There is, however, little historical justification for the view that towns and cities are a burden upon the economic development of countries. On the contrary, they are essential to economic development at a national level, and particularly that of the rural areas.

Perhaps their most important role is in providing markets for rural produce. Without the urban areas, farmers have few if any outlets for their produce. They must therefore remain at a subsistence level, unable to make any capital investments in better tools, land improvements or environmental protection measures. In the past, in many parts of the developing world, such subsistence farmers could survive by moving to new farming areas when the fertility of their lands had been depleted. But now, as a result of population growth, the option of opening new lands is closed to many; the only way they can survive is by intensifying their farming methods. This can only be done by investments which are paid for by the sale of produce to the urban areas.

Cities also provide jobs. For those at the bottom of the urban economic scale, the earnings are minuscule. But they are more than can be obtained by the landless or those with inadequate subsistence holdings in the rural areas. People flee to the cities because, however bad conditions may be there, they are better than they experience in the rural areas. Famines are an almost exclusively rural phenomenon.

But cities are also enormously important in a much broader cultural, economic and social sense. The French historian Braudel said:

> "Cities, towns, are watersheds of human history...Their revival in Europe in the eleventh century marked the beginning of the continent's rise to eminence. When they flourished in Italy, they brought the age of the Renaissance. So it has been since the city states, the polis of ancient Greece, the medinas of the Muslim conquest, to our own times. All major bursts of growth are expressed by an urban explosion" (Braudel, 1981).

Towns and cities are therefore crucial to the survival of the rural areas. They provide the markets without which any development of agriculture is impossible. They also provide a refuge for the surplus or marginally productive, rural population as agriculture becomes more capital intensive and productive. It is not a matter of choosing between one or the other, but of ensuring that there is an effective and fruitful symbiosis between the two.

Urban Electrification as Part of a National Development Strategy

Urban electrification clearly has a role to play in the national development of Third World countries. It needs to be seen as part of an overall national development effort and deserves to be given more attention, and support, than it has obtained to date.

From the viewpoint of the electricity utility, it is crucial that its urban supply systems operate economically and efficiently. Inevitably they account for the bulk of sales and revenues. They also provide the technical, financial and organizational base from which effective rural electrification programmes can be launched.

From the viewpoint of urban dwellers, electrification marks a major upward step in their standards of living. It is a safe, clean effective and uniquely versatile source of energy which enables them to function more effectively as human beings and members of society.
Urban electrification also improves the functioning of the urban areas. It makes them better places to live. It helps in the creation of employment opportunities, particularly in the services sector. It enables them to act not just as a dumping ground for those who cannot survive in the rural areas, but as a positive pole of attraction.

Perhaps most importantly of all, healthy well-functioning cities are essential to the well-being of the rural areas around them. They provide the markets and the services which are essential to rural development.

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MANAGING RURAL ENERGY TECHNOLOGIES: THE EVOLVING POLICY IN FIJI

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DOE

The Present RE Policy

The Government Rural Electrification Programme initiated by a Cabinet Decision of 10 July 1973.

Mandate

The Government Rural Electrification programme intended to provide self-contained electrical power supply schemes in remote areas.

Condition of Participation

(a) The Public Works Department (PWD) is responsible for implementing the Government policy.

(b) Requests for electrification will be forwarded to the PWD via District Officers, Provincial Councils or directly to PWD.

(c) Surveys will be conducted by PWD after payments of 50% of a basic contribution. Villages will be informed of the amount of this basic contribution. After payment of this contribution, villages will be listed on first come first served basis.

(d) The cost of the projects will be funded jointly by the village communities and government at a proportion to be set from time to time by Cabinet. The present ratio is government 5/6, community 1/6, 4 with maximum per household of $50.00.

(e) The maximum size of eligible villages will be determined from time to time by Cabinet. Initially this maximum was set at 100 households.

(f) PWD will provide 2 x 20W lights
1 x 10A GPO per house.

The whole installation of 1 generator set, power house reticulation, protection fuses will be to FEA standard. A 200 litre drum of diesel fuel will be provided for initial operation.

(a) Fore extension after the initial installation, there has to be a minimum of 5 houses who will pay 1/6 of total cost or $50.00 per house.

(b) For extension after the initial installation, there will has to be a minimum of 5 houses who will pay 1/6 of total cost or $50.00 per house.

(c) The project will be owned by the village except for the operation set and power house which shall remain the property of Fiji Government who, through PWD, reserve the right to utilize such generating equipment to equip new projects or change existing sets.

(d) Villages to pay a maintenance fee of $100.00 per year. This covers servicing visits twice a year to PWD technicians. This includes:

(i) change of oil
(ii) change of oil filter
(iii) change of air filter
(iv) change of fuel filter

All minor defects and adjustments will be rectified by the visiting team and major defects will be noted. If they cannot be done immediately, arrangements are made to rectify them if the accrued cost of such repairs does not exceed six times the annual maintenance costs ($600.00 currently). The difference must be met in full before works commence.

Repair work due to abuse and unauthorized wiring will be charged at full cost to the village.

No charge will be made for travelling between base workshop and settlement and charges will relate strictly to material and wages expended on maintenance and repairs.

<u>Amendment to Original Policy</u>

(a) Cabinet meeting 21/12/82 reiterated that PWD should remain responsible for rural electrification.

(b) Instead of a maximum of 100 houses as minimum of 20 houses was set.

(c) Generators were standardized at 10 kVA, 25 kVA. In 1982 design watts was set at 100 VA. Standardized at 3.5, 7.5, 13.5, 20 kVA. Now in 1990 200 VA design ways with standard generator sets at 7.5, 18, 25 kVA.

(d) In January 1989 Cabinet decreed that "there should be a firm policy to facilitate the supply, extension and maintenance of ...... electricity to rural areas, in particular, villages ...."

<u>Some Relevant Costs</u>

(a) Capital Costs

Cost per household in 1974 ~ $443.00
Cost per household in 1990 ~ $1280.00
(30 household village schemes).

(b) **Running Costs**

Optimal running for diesel. 200 litre drum.
Conservative estimate given by villages.
3.5 kVA for about 20 houses running 4 hrs/day
= lasts about 8 wks = 8 x 7 x 4 = 224 hrs
= 200/224 = 0.893 lts/hr

7.5 - 15 kVA = lasts 6 weeks = 8.6 x 7 x 4 = 168 hrs
= 200/224 = 0.893 lts/hr

20 - 35 kVA about 4 weeks = 4 x 7 x 4 = 112 hours
= 200/112 = 1.78 lts/hrs

Construction on Diesel RE Schemes Under Existing Policy

The policy and cost options in 1973 were reasonably in line; the $50 per household or 1/6 of total cost on an investment of $443 per household was a realistic choice. However, in 1990, the 1/6 options is left behind and villages pay only the $50 per household option with government effectively providing 96% of the capital.

Up until 1990, some 150 villages schemes have been installed, at the rate of about 10 a year. Given that there are over 1,000 villages and settlements, at the present rate, it will be a 100 years before everyone has the benefits of a diesel RE scheme. This cost at today, rate, would exceed $40 million dollars on capital investment only.

What really are the benefits of such a scheme as outlined earlier? In 1990 each household is eligible for 200 VA for up to 4 hours a night. What can the householder realistically use this power for other than lighting? Ironing? An electric kettle? A video system? A sewing machine? What happens if everyone plugs in an electric kettle at the same time? We have seen GPOs with up to 4 extension cords to extra lights, cassette players, rice cookers etc. How do you limit the current appropriately when appliance use increase - with positive temperature co-efficient thermistors or miniature circuit breakers? When do you upgrade plant to accommodate increasing capacity and who pays?

What happens when the generator set is shut down at 10 o'clock? Very few human beings sleep without some sort of constant illumination available whether it's a fire, night light, a light on in a passageway or an exterior light. Thus the villagers ar still within the kerosene culture - cash for purchasing fuel, lights and maintenance of lights.

What do the schemes not provide? Well, for a start you cannot run an electric refrigerator and there is no power available for any rural process industry. Even so called cottage industries are excluded by virtue of the time - the early evening, a time when most households are gathering together at the end of the day, kids to be put to bed etc.

Indeed it is because of the concerns such as these, coupled with cash flow constraints on operating costs which are affecting some of the schemes that we have initiated a wide ranging survey of the diesel RE schemes. This survey, funded by PEDP aims to look at about half of the schemes in some detail to find out the inherent constraints, increase of appliances etc. We are also asking for subjective opinions on the benefits of electricity.

In summary, therefore, the diesel RE schemes really only provide villagers with improved lighting for a 4 hour period, at a cost equivalent to that paid by their grid connected countrymen. The latter however, may also have a fridge and perhaps a sewing machine which they can use during the day. The day to day costs of the diesel schemes are about the same than equivalent kerosene lighting costs.

Given the severe constraints implied it is difficult to justify such huge Government subsidies in capital and maintenance and the imposition of inherent fuel costs on a limited cash economy. So with such a huge task ahead to develop some of the fruits of development into the rural communities it is instructive to look at some of the alternatives.

The "Spreading of Money Around" Alternative

(a) Budgetary Parameters

Rural electrification policy is inevitably constrained by budgets. Governments allocate a certain sum each year, increasing a little annually perhaps to keep in line with cost increases. So, whatever the policy position each year only a few more schemes can be installed and the waiting list grows.

(b) The Solar Alternative

In Fiji, the majority of the rural villages served, (or applying to join) the RE schemes are compact, communal villages with a strong sense of community. Invariably a substantial church building dominates the village, somewhat similar to rural European landscapes. In many villages, church or general community activities are an integral part of evening activities.

We have therefore installed a variety of pilot projects aimed at providing improved lighting into the community focal points, be it a school, community hall or church. It must be emphasized here that this was just as much a result of demand than of policy tinkering. Using an appropriate number of separate solar panel systems (2 panels, 1 battery, 1 controller, 2 lights) a church capable of seating nearly 300 people has been installed which we are monitoring.

At a capital cost of $5,000, 7-8 installations, that is 7 or 8 villages, could be provided with something for the same cost as a single village with every house wired. Suddenly the waiting list disappears and an intermediate goal is in sight.

With the possibly imminent introduction of TV into Fiji in mind we arc just introducing solar powered video pilot projects near to Suva for monitoring. The purpose of these is twofold:

(a) to demonstrate to Government planners etc. that solar energy could provide the power for TV in rural areas. This could be substantially cheaper than 1000 villages clamoring for diesel installations as soon as TV is introduced.

(b) in conjunction with National Video center and Rural Development ministries to ascertain educational and training potential of video. Given the enormous spread of video and the heavy cost implications of providing quality TV, this latter option presents interesting possibilities.

The "Get It While You Can" Alternative

(a) Budgetary Parameters

In the solar alternative, it is shown how the financial constraints of Government budgetary allocations limit the effectiveness of the policy it wishes to promote. However, when the scene shifts to international donor funds, a completely different set of financial realities dictate. At this level of soft loans, interest free loans, direct grants etc, alternatives are finance driven and long term dreams perhaps have to be seized and implemented. If not, they will remain a dream if that project is to be installed at commercial rates of interest some time in the future. It is not unrealistic to forecast a Fiji future of nearly everyone connected to renewable energy driven grids. To this end it is active policy to use aid funds to extend the existing grid wherever and whenever possible. Load centers developed by stand alone diesels are a positive move towards this goal.

(b) The 24 Hour Supply

Centralized systems providing 24 hours supply to several villages on islands is a serious consideration under these conditions. In most cases installations such as these would evolve from perhaps an established load center on an island (ice plant, sawmill, etc.) with transmission to other villages who may or may not have had stand alone RE schemes. In this case diesel generator sets provide the flexibility for load growth. Many commentators, within the Pacific and elsewhere, suggest that it takes a minimum of 4 years for the potential, that a 24 hour supply gives, to be begun to be realized. This allows time for alternative base load technologies to be assessed - wind, wind/diesel, solar/diesel, wave etc.

The "Kick Start or Return on Investment" Alternative

There is but anecdotal evidence that improved lighting, as supplied by existing schemes, leads to improved school grades. If, however, Government adopted a policy of heavily subsidizing power to promote rural industry with household electrification as a benefit and not the justification then some returns can be felt, not only to the community but to the national as a whole. This surely would be a more rational use of limited annual allocations with subsidized diesel generators.

In Fiji, we are also proposing, with aid donors, a series of integrated trial projects based on steam plants providing the power for sawmills. The rationale for this is the huge number of 20-50 ha community pine plantations too remote from recognized urban or international markets to be economic, a legacy of the rampant plantings of the 1970s. These plantations, well managed by the villages in co-operation with Forestry Department, are part of the large resources enjoyed by many villages, the others being copra, cocoa, fishing, yaqona etc. Small sawmills capable of processing the P Caribea, with waste and offcuts fuelling the plant (process heat for crop drying and household electricity as a by product), providing a nucleus for rural development and income generation. The obvious area of timber treatment is being addressed to ensure sustainable local marketing potential.

Existing Alternative Energy Projects

We have a committed policy to upgrade and bring into the PWD maintenance umbrella all existing pilot projects in Fiji. Obviously with same rationalization, we are slowly upgrading the 350 or so individual house solar lighting installations and the micro hydro and steam plants installed in Fiji during the past decade. All of these projects were installed and then left to their own devices without anticipated assistance and at complete variance with Government policy on maintenance with respect to the diesel schemes. The details are not presented here but with regard to the solar equipment. UN funded surveys have clearly shown that the systems were undersized. Two panels, battery, controller, 2 lights and a night light will be offered, the controller in a legally sealed box to avoid tampering. With this system and with regular maintenance a more realistic long-term evaluation of our options can therefore be undertaken.

Import Tariffs and Duties

Any promotion of alternative technologies by the Government policy arm must be accompanied by a realistic, coordinated and sympathetic approach by the Finance arm to that policy. We raise this issue because it is particularly relevant to the long term health of any rural energy technologies, the sector with the least available cash.

In Fiji, complete solar systems can be imported with total tariffs of 7.5% which is favorably geared to promote use of this alternative. However, it is usually very expensive to import complete systems because whoever is selling the complete systems has taken their percentage. The component parts, however, have much higher tariff rates with batteries topping the list with 57.5% total import duties. Such tariffs dictate that the recipient purchases a locally made replacement battery suitable for a vehicle or short circuits the controller rather than pay the 32% tariff. This is generally unrealistic on these counts:

(a) apart from aid funded schemes, the import tariff structures is holding back any commercial expansion;

(b) there is no conflict of interest of these components for solar systems with other widely used components; and

(c) the rural sector predominantly using this equipment has the least available money.

The current crisis in the Gulf, and resultant high oil prices, present an opportune moment to push through uniform and consistent import tariffs on the alternate technologies that we are actively promoting.

Summary

To summarize the policy alternatives therefore, we are considering a variety of options for future direction of providing the rural communities with some of their realistic demands.

We must assume that the long term goal is for most people to be connected to a renewable energy grid; how we get there, equitably and realistically determines the policy. No economic analyses are presented here because we are still in the process of assessing all the options. Details of maintenance costs, who pays for replacement parts, village contributions, electricity tariffs and collections in outer island 24 hour supply etc. are similarly not presented. We have simply tried to show how with both limited budgets and aid funds, fairly realistic policies can be considered to provide something for everyone and, indeed, useful power for rural development rather than heavily subsidized lighting schemes to individual houses in a comparatively few villages.

PROVISION OF FUEL TO RURAL COMMUNITIES: NOTES ON SELECTED PACIFIC ISLANDS

George Tavanavanua
PEDP
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Introduction

One of the difficulties faced by the various Pacific Islands governments in the evaluation of energy options for outer islands and rural communities is the absence of accurate information on real costs paid for fuels such as kerosene (for lighting and cooking), petrol and diesel (for small electricity generators used in these communities). Except for a very few countries, most governments as a matter of policy and for the sake of simplifying the control of fuel prices do provide some cross-subsidies in fuel costs for these rural communities. However, one of the difficulties faced by most governments is the identification of these subsidies and their quantification. Some governments have even reached a stage where they have completely lost sight of these subsidies.

This paper addresses the costing of fuel to outer islands and the rural communities and endeavors to identify and quantify hidden costs associated with rural fuel supply. It then goes on to suggest options for freighting of fuel to minimize costs to rural consumers.

Redistribution Costs

In September of this year, PEDP commissioned Mr Ken Beck, a Petroleum Consultant with wide experience in the Pacific Islands, to investigate redistribution costs to rural areas in Fiji, Tonga and Papua New Guinea confirming real costs of supply and the price paid for fuel at a sampling of rural locations and identifying any element of subsidy in the prices of fuel being paid. (Refer to PEDP Report No. REG 90-7, November 1990, forthcoming).

In the analyses provided in this study, the actual costs of transshipping petroleum products from main port supply points to selected rural locations were established. Detailed examination of methods used and the associated costs were carried out with the various cost elements being authenticated by confirming rates with shipping companies, trucking companies and other parties that provide the services.

The final costs shown for the various locations can, in the overall sense, be confidently accepted as factual. When compared to the government approved differentials these supply costs in general do closely agree. There are instances of over and under recovery identified but these differences are considered inconsequential for the purposes of the study.

Papua New Guinea, because of the vastness and complexity of the country and population distribution, has a great number of outlying consumption points which is reflected in there being 370 approved differentials adopted in the Price Control System.

Many of these differentials were established some 15 years ago and are overdue for revision, though it may be a daunting exercise. This is especially so in cases where transportation modes have changed over the years. For example, there are instances where the differential was based on air freighting product to a particular location when the differentials were first calculated, whereas today road development has made it possible to supply the same location by road.

One element of expense associated with distributing petroleum products which is not costed in the drum trade is the fuel losses through evaporation, leakage and drum decanting. These losses contribute on average up to 1501"o of total dram content. This means that drum supply commonly used for outer island locations should reflect that, on average, a 200 litre drum of fuel translates to 170 liters of fuel used on a remote location. Such losses cannot be viewed as a transshipment expense as these are experienced irrespective of location.

Government and Industry Subsidies

The Beck study did not identify any direct subsidies provided by either Governments or the industry in any of the three countries covered except for the "C" Class power stations which is covered separately below. However, the mechanics of the price control systems used in the three countries provides for hidden cross-subsidies on price-controlled products such as petrol, diesel and kerosene.

In PNG, for example, there are five primary ports and over fifty other seaboard bulk depots, agencies and distributors. In the price control system in place, each oil company totals all distribution costs for their PNG business, covering all distribution facilities which they operate. The total distribution costs are then used to calculate an average distribution cost per litre of product. As a result, the Port Moresby consumers, where most of the volume is marketed, subsidize the cost of fuel to consumers in smaller markets like Alotau and Kavieng. The difference in distribution cost between a major terminal compared to an inland bulk plant or small coastal redistribution depot can be as high as 8 toea per litre (equivalent to 8.5 US cents 1/ per litre) which is the magnitude of cross-subsidy in fuel price given to customers serviced through this smaller depot.

To quantify this element of cross-subsidy will require more detailed analysis with the assistance of the oil industry.

Another example of cross-subsidy in consumer prices is right here in Vanuatu where the government, as a matter of policy, requires the oil companies to sell fuel to outer islands customers at the same market prices charged to Luganville and Efate customers. This subsidy amounts to 7.7 Vatu per litre (or 7.1 US cents 2/ per litre) in freight subsidy which is absorbed by customers in these two main markets as part of the total operating cost claimed by the oil companies in the pricing formula. A similar cross-subsidy exists in Kiribati.

1/ Exchange rate of US$1.00 = 0.937 Kina; 100 toea = K1.00

2/ Exchange rate of US$1.00 = 114 Vatu.

These subsidies give petroleum fuel based energy sources such as electricity generators an artificial advantage over any other options including PV Systems which may lead to distortions in investment and natural resource allocation.

"C" Class Minor Power Stations - Papua New Guinea

Another type of subsidy provided to rural customers is based on a direct government grant. In PNG, for example, the Central Government provides an annual grant of 6.5 million kina (approximately US$7.5 million) to support its rural electrification initiative through what are termed "C" class minor power houses. There are about 90 such power stations in the country. This fund is to cover the replacement of equipment, maintenance, metering, revenue collection, fuel and oil costs, and operators wages. The Ministry of Finance is responsible for the equipment replacement, maintenance, metering and revenue collection for which K3.0 million is provided and the balance of K3.5 million is transferred to the Bureau of Management Services in the Provincial Councils for the purchase of fuel and oil, and operators wages. Typically each of these power plants support 20 - 100 consumers making the subsidy approximately 83,600 for each consumer. The revenue collections from these C-centers only cover about 1% of their costs.

One of the difficulties being experienced by the government in this scheme is the determination of the exact costs for power production due to lack of proper controls and records. However, it is generally conceded that at some, if not all, of these outlying locations the fuel which is intended for power generation is also being siphoned for use on road vehicles and tractors and other equipment requiring automotive distillate. This complicates the proper allocation of costs and the establishment of the level of subsidy being provided for fuel at each location. It is also known that some stations historically exhaust their fuel funding before the year end and this has led to the closure of some stations for various periods in the past.

To provide some indication of the difficulties experienced in ascertaining accurate costing Beck, reviewed details of costs to Menyamya, an inland location serviced from Lae (see attached map). He established that fuel for Menyamya in September 1990 cost 44 TPL 3/ (the equivalent of 46 US cents per liter) delivered but in the submission made by the Provincial Government for the 1991/92 Central Government funding a figure of 33.5 TPL (or 35.7 US cents per litre) was used. Likewise the total volume for this power station could not be correctly ascertained as according to the submission, annual usage was 45,000 liters whilst in an analysis completed by the Ministry of Finance the volume was estimated at 149,000 liters for the same location.

Detailed investigation and the establishment of improved management controls in all C-centers are needed if government wishes to establish control over cash.

3/ Toea per liter.

Price Control Procedures

The three countries covered in the Beck study have price control systems for the determination of market prices for petroleum fuels. Basically all three countries adopt the same procedures in establishing wholesale and retail selling prices in their respective markets. The system considers each element of costs from the Loading Port to the ultimate main port sale location and arrives at an approved wholesale selling price. For retail prices, a fixed margin is then added to the wholesale price.

The system requires the price controller to first verify each element or component of the price build-up cost from the loading port to the cost of fuel delivered to wholesale customers and approves each element of cost as submitted by each marketing company. The elements considered in the pricing formula include:

F.O.B. Loading Port
Ocean Freight
Insurance
Ocean Losses
Demurrage
Port & Harbour Dues
Wharfage
Additives
Import Duty
Inland Losses
Distribution Costs
Return on Investment

The main ports recognized for this exercise are: Port Moresby, Lae, Arawa, Madang and Rabaul in PNG; Suva and Vuda Point in Fiji; and Nuku'alof in Tonga.

To establish the selling prices at rural locations, the price control authorities in these three countries also review freighting and handling costs from the main supply ports to arrive at differentials which are to be added to the main ports wholesale and retail prices to arrive at the new market prices at these rural locations.

The timing for the price reviews in each country varies. In PNG the landed cost is reviewed monthly, whilst in Fiji and Tonga it is done on a quarterly basis.

The only areas which continue to be the subject of disagreement between the Pricing Authorities and the oil companies are the choice of the benchmark company and their return on investment (Profit Margin). The countries also adopt different philosophies in establishing price controlled market prices: in Fiji the lowest cost marketer is the benchmark company; in PNG Shell has historically been treated as the benchmark company; and in Tonga the Competent Authority sets prices for each company with market prices being determined by consumers in the market, normally the lowest prices approved for the different products where competition exists.

It appears that the Industry and Governments have cooperated closely over the years with good accord having been reached between the parties.

Freight Costs to Outer Islands

Differentials provided in the costing of fuel to rural locations depend on the mode of supply. This can be in bulk or 200 litre steel drums. Some rural communities with sizeable demand and favorable physical conditions can justify the setting up of bulk handling facilities to warrant the needed investment from oil companies or local entrepreneurs to convert to bulk supply. Other locations cannot justify the high investment needed for such facilities and can only continue to be supplied through the shipping of fuel in 200 litre steel drums as deck cargo on local vessels. Then there are locations that can only be supplied in bulk for high throughput fuels, with other minor products supplied in drums.

An analysis of a few locations covered in the Beck study under the three categories quoted can assist in improving our understanding of how costs can vary widely:

Rural Bulk Supply

Labasa (Fiji) and Kavieng (PNG) are representative of this category of locations employing LCT 4/ for bulk supply. Labasa, which is located in Vanualevu, the second largest island in the Fiji group, is supplied Petrol, Automotive Distillate, Dual Purpose Kerosene and Fuel Oil in bulk using the Local Coastal Tanker, Pacific Rover. The cost of transshipment of fuel in bulk from Vuda Point to Labasa amounts to 1.6 Fijian cents per litre (approximately 1.1 US cents 5/ per litre) which makes up the bulk of the government approved differential for this location.

For Kavieng, which is supplied in bulk ex Rabaul, the equivalent bulk fuel freight cost is 2.62 toea per litre (or 2.45 US cents per litre) for Petrol, Automotive Distillate and Dual Purpose Kerosene.

Rural Supply in Drums and Bulk

Kiunga (PNG) and Somosomo (Fiji) are examples of locations supplied in this manner. Supply costs from the main ports for each of these locations are detailed below:

Table 1: SOMOSOMO FUEL SUPPLY COST
(Costs in Fijian cents per liter)

Cost Element	Bulk	Drums
Outward Cartage	--	--
Freight	2.09	6.75
Inward cartage	--	--
Drum return*	--	3.00
Total cost	2.09	9.75
or US cents/liter	1.44	6.73

Note: Drum return includes cartage and freight costs.

4/ Local Coastal Tankers.

5/ Exchange rate of US$1.00 = F$1.45.

Table 2: KIUNGA FUEL DELIVERY COSTS
(Costs in Toea per liter)

Cost Element	Bulk	Drums (1)	Drums (2)
Outward Cartage	0.40	1.00	1.00
Freight including wharfage	3.20	12.75	10.65
Inward cartage	--	0.63	0.63
Drum return including cartage and wharfage	--	7.67	7.67
Total cost	3.60	22.05	19.95
or US cents/liter	3.85	23.53	21.29

Note: Drum return includes cartage and wharfage.
(1) Flammable fuels - (2) Fuels and oil other than flammables.

These two locations exemplify the high penalties associated with drum supply. The difference between drum supply versus supply bulk in Somosomo is of the order of 5.29 US cents per litre and that for Kiunga is 19.68 US cents per litre for flammable liquids and 17.44 US cents per litre for other fuels.

Rural Supply in Drums

Examples of total supply in drums include Kadavu in Fiji, Niuas in Tonga and Morehead in PNG. Details of freight costs to each of these locations is set out below.

Table 3: NIUAS (TONGA) FUEL DELIVERY COSTS
(Costs in Tongan Seniti 1/ per liter)

Cost Element	Bulk	Drums
Outward Cartage to wharf	--	0.60
Inward/Outward Wharfage	--	--
Outward Freight	--	9.00
Empty Drum return freight	--	5.50
Empty Drum cartage	--	0.30
Total cost	--	15.40
or US cents/liter	--	12.19

Note: There is no wharfage charged on cargo; stevadoring is covered by Ship's crew and is included in the freight charged.

1. Exchange rate of US$1.00 = T$1.263.

Table 4: MOREHEAD (PNG) FUELS DELIVERY COSTS
(Costs in Toea per liter)

Cost Element	Drums (1)	Drums (2)
Outward Cartage	0.60	0.60
Freight including wharfage	9.98	8.91
Drum return including cartage and wharfage	5.75	5.75
Total cost	16.33	15.26
or US cents/liter	17.41	16.07

Note: (1) Flammable fuels - (2) Fuels and oil other than flammables.

Table 5: KADAVU (FIJI) FUEL DELIVERY COSTS
(Costs in Fijian cents per liter)

Cost Element	Drums (1)	Drums (2)
Outward Cartage to wharf	1.12	1.12
Freight	4.00	4.12
Cartage to depot	1.00	1.00
Drum return including cartage	2.80	2.80
Total cost	8.92	9.04
or US cents/liter	5.05	6.26

Note: Drum return includes cartage and freight costs.

From the above analysis, it is clear that freighting of fuels in drums imposes a heavy penalty on the rural consumer. Apart from this direct penalty, there are other penalties that should be considered. These include penalties through product and drum losses through handling and evaporation at both ends of the delivery run as well as losses on the vessel during transit between the source location and destination. On top of these losses are added the decanting losses, as it is impossible to account for every litre of fuel loaded when emptying the drums at the destination. As previously stated, the total of these losses can account up to 15 % of total content.

How can these extra cost penalties be avoided by rural customers? is it possible to save on any item of costs tabled above?

The answer is "yes" but it will require the co-operation of the storeman checking, cleaning and filling the drums and the cartage workers who load and unload the trucks at supply.source location, the stevedores that load the vessel, the ship's crew and people that handle the drums at destination. If all the necessary care is taken, the loss factor can be reduced to single digits. However it is difficult to achieve a total elimination of all losses in the drum trade and a loss figure of 5% would be an excellent result.

Other Freighting Options

Obviously, it would be preferable to convert supply to bulk where the economics can sustain such an option. This would not possible for all locations unless such moves were completed through aid funds or other such sources of investment finance.

Are there other alternatives to the use of steel drums in the affreightment of fuel to rural locations which can improve on freight and transshipment costs?

The "fabridrum", a 500 US gallon synthetic type rubber bag is an alternative which is currently being evaluated by PEDP with the co-operation of Mobil Oil Fiji who are co sponsors of this work. The materials were ordered in late 1988 and the programme commenced in May 1989. This programme is to confirm the practicality and the financial benefits to be gained from the use of the container under Pacific Islands conditions. The financial results to date are quite favorable and can best be illustrated drawing a comparison between the use of the fabridrum and the 200 liters (55 US gallon) steel drums. Four main criteria were used in this comparison:

(a) Capital investment;

(b) Preparation, filling, handling & storage of the containers;

(c) Freight rates and costs; and

(d) Losses experienced.

Assumptions:

This evaluation is based on the following assumptions

(a) One 200 litre drum is equivalent to 55 US gallon capacity and costs US$21.00;

(b) One 500 US gallon fabridrum costs US$3,800;

(c) 66,000 US gallons of fuel were to be moved to Somosomo (Fiji) from Suva, in equal monthly quantities;

(d) A 200 litre steel drum averages three rerun trips to Somosomo before being written off.

Capital Requirement

If 66,000 US gallons were to be moved in twelve equal monthly shipments, 5,500 USG will need to be moved monthly.

(a) If freighting were to be done in drums, total number of drums required will be 1600 drums. With each drum lasting three trips, at least 400 drums will be required. At US$21.00 per drum = US$8,400 per annum. Over a ten year period (the assumed life span for a fabridrum 6/), the total cost of drums needed for this requirement would be US$84,000.

(b) To move the same quantity of fuel using fabridrums would require a total of 3 x 500 USG fabridrums with each drum making at least two trips a month. At US$3,800 each, fabridrums required would cost US$11,400; fabridrum accessories including pump and tow bar would cost an additional US$10,000; or a total cost of US$21,400.

Capital requirement would therefore be US$62,400 cheaper.

Preparation, Filling and Handling

To fill drums would cost an estimated 1.0 Fijian cent per litre more than filling fabridrums. This is equivalent to 2.6 USC per USG. The use of the fabridrums would therefore provide a saving of US$2,400 per annum.

Freight Cost

The cost of freighting a fabridrum from Suva to Somosomo is F$80 full and F$20.00 empty, or a total of F$100 per drum on a return trip which is equivalent to 20 Fijian cents per USG or 13.8 USC per USG. Freight cost, including cartage, using fabridrums amount to US$9,108 per annum.

On the other hand, freight cost using drums (obtained from the Beck study) is 9.75 Fcpl or 25.5 USC per USG or an annualized cost of US$16,830.

This provides an annual saving of US$7,700 in the use of fabridrums.

Losses

A major cost in the freighting of fuel in drums is product losses. It has been estimated that, on average, drum losses amount to approximately 15% or 30 liters per drum. These losses arise from leakage, evaporation ana in the decanting of drums at destination. For the 12,000 drums annual requirement for Somosomo, losses would amount to 1200 x 30 = 36,000 liters or 9,500 USG which, at F$1.00 per litre landed at Somosomo, would amount to F$36,000 or US$25,000 per annum.

In the case of freighting in fabriurums, there is no air space allowed inside the container and the container is air-tight restricting vapor space hence losses.

Total annual savings through improved loss control in using fabridrums is estimated at US$25,000.

The above loss calculations do not take into account drum losses due to damage in handling and shipping and the non-return of drums. If these were taken into account savings would be higher.

6/ The life-span for a fabridrum can be as high as 20 - 30 years; some fabridrums from the Vietnam War are still in use in South East Asia.

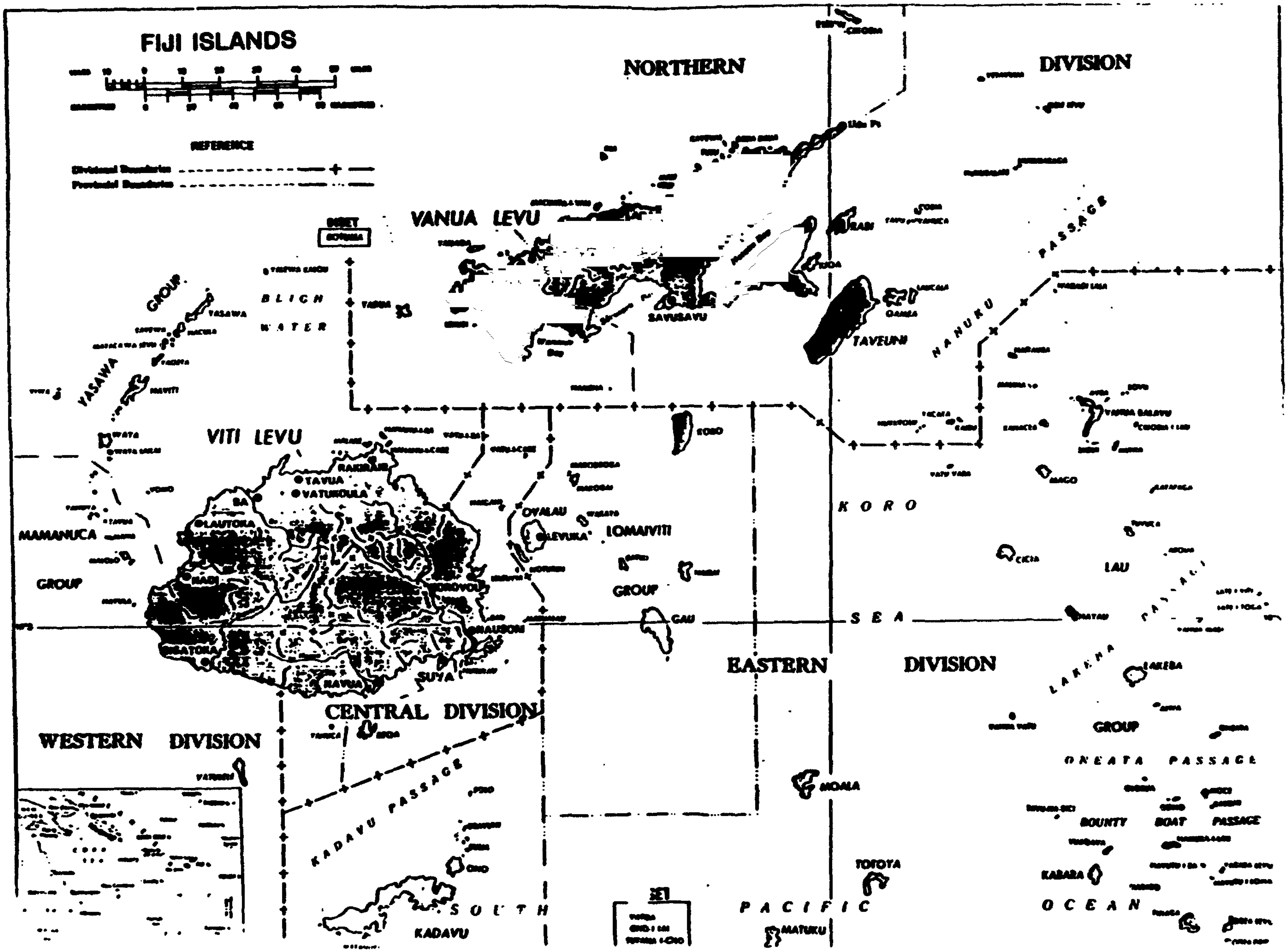
To summarize, annual cost savings in the use of fabridrums when compared to the use of metal drums in the freighting of 66,000 liters of fuel per year to Somosomo, as an example of an outer island location, are as follows:

Table 6: ANNUAL FREIGHT SAVING IN THE USE OF FABRIDUMS (Instead of 200 litre Drums) to Somosomo

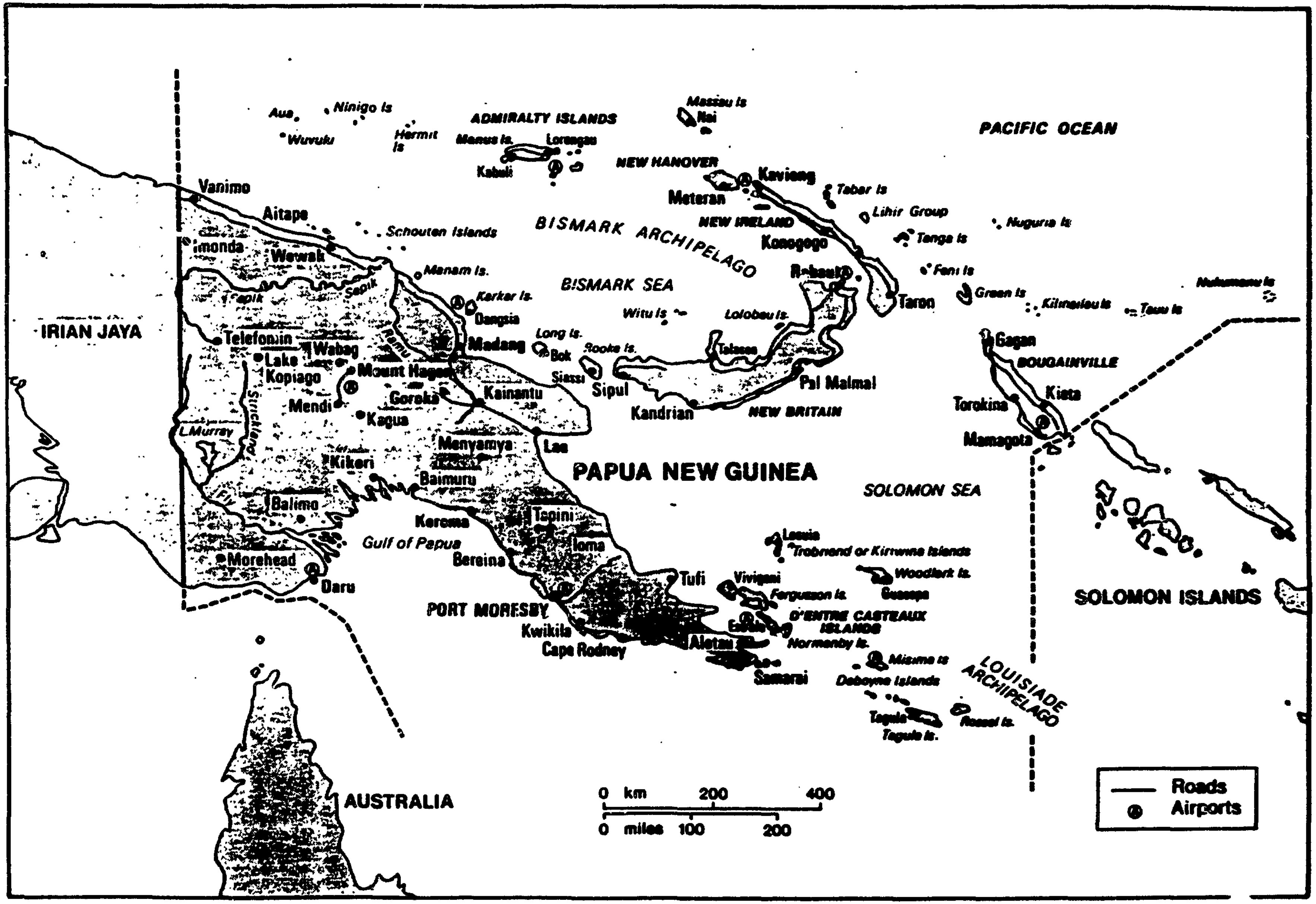
Item	Saving in US$
Capital cost	6,260
Preparation, Filling & Handling	1,980
Freight paid	7,700
Product losses	25,000
Total annual savings	40,940

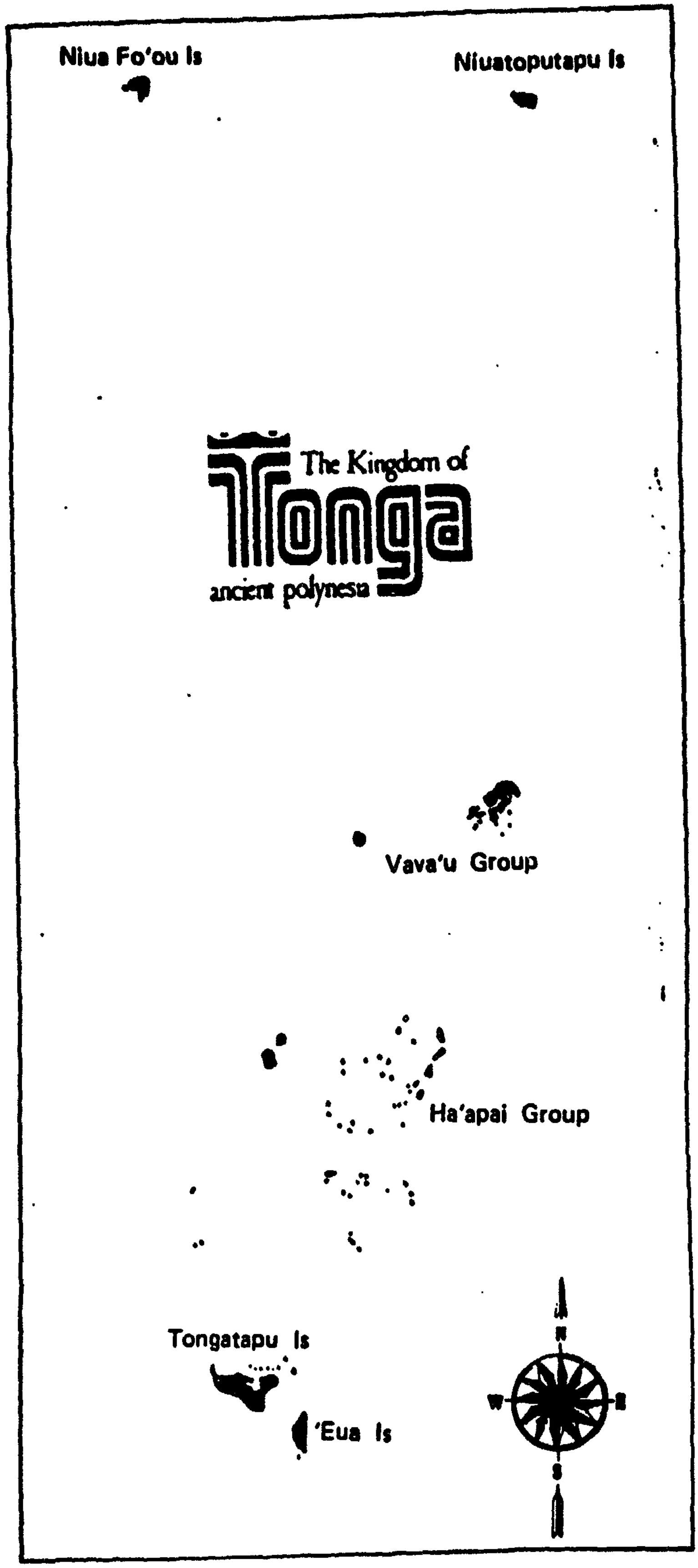
The evaluation programme to date has confirmed that the use of the fabridrum can substantially lower the freight cost for fuel supply to outer islands and rural locations for some markets with inadequate volume to qualify for bulk supply. It is also important to establish the threshold minimum volume below which it would still be necessary to use drums.

This is part of the programme still to be compl... ogether with establishing the suitability of the container under different Pacific Island conditions. One of the three bags in the initial batch ordered has been relocated to Rarotonga for supply to outer islands locations in the Cooks and we hope to be able to report to governments in the region by June 1990 on the results of the study.


FIJI ISLANDS
REFERENCE
NORTHERN DIVISION
VANUA LEVU
SAVUSAVU
TAVEUNI
NANUKU PASSAGE
BLIGH WATER
YASAWA GROUP
VITI LEVU
TAVUA
VATUKOULA
RAKIRAKI
BA
LAUTOKA
NADI
SIGATOKA
NAUSORI
SUVA
NAVUA
MAMANUCA GROUP
WESTERN DIVISION
CENTRAL DIVISION
KADAVU PASSAGE
KADAVU
OVALAU
LEVUKA
LOMAIVITI GROUP
GAU
KORO
KORO SEA
LAU GROUP
LAKEBA PASSAGE
EASTERN DIVISION
ONEATA PASSAGE
BOUNTY BOAT PASSAGE
KABARA
MOALA
TOTOYA
MATUKU
SOUTH PACIFIC OCEAN

Papua New Guinea

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MANAGING HOUSEHOLD ENERGY CONSERVATION

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Introduction

I have been asked to present a paper on Managing Household Energy Conservation in Fiji. My task is quite difficult given that there is no clear policy on Managing Household Energy Conservation. However, we do have some general guidelines that help us address this issue and I intend to highlight what the Department of Energy is doing in relation to the overall rural household energy sector.

Allow me to start by touching on the National Energy Conservation Policy.

Energy conservation in the context of Fiji comprises three separate issues:

1. Import substitution of fossil fuel;
2. increasing energy demand in an energy efficient way; and
3. direct energy saving as the term energy conservation implies.

This conservation programme encompasses the following objectives:

(a) Building up an accurate data base on end-user energy conservation by sector and fuel type;

(b) Identifying buildings and industries with conservation potential;

(c) Conducting audits in selected buildings and institutions and assessing the economics of conservation measures;

(d) Providing technical information and advice to commercial and industrial sectors on energy conservation measures;

(e) Providing information to the public on energy savings options in private transport and residences;

(f) Altering financial incentives and tariffs so as to promote investment in energy conservation; and

(g) Building up national capabilities in energy conservation through encouragement and support of local consultants, engineers and contractors.

The National Energy Conservation Programme, which has been in existence since 1982, places more emphasis on energy conservation in urban areas. The work initially tended to be concentrated on energy conservation in government premises, the industrial and commercial sectors. The strategy was to target high energy users, especially the industrial sector (in line with the National Development Plan Policy of reducing the volume of imported energy per unit GDP). It is easier to make an initial impact on these high energy users than individual consumers.

A point to note is that the readiness of the industrial sector to invest in measures to improve energy efficiency may be related to anticipated changes in the price of energy. Depending on how the oil market continues to react to development in the Middle East these measures may prove more advantageous than anticipated at their time of implementation. A SPEC sponsored assessment of the conservation programme in both public and private sectors conducted by Enersonics Limited in 1987 showed encouraging results (excellent returns on investment have been achieved in almost all cases).

Our National Energy Conservation programme was initiated prior to the Fiji Electricity Authority bringing the Monasavu Hydroelectric plant on line. The excess of capacity that then existed with Monasavu provided a strong incentive for FEA, a government statutory body to maximize sales of electricity. In consequence energy conservation measures since have focussed on large government users, particularly hospitals. The activities focus mainly on cost-effective ways of reducing electricity consumption without adversely affecting outputs of goods and services or working conditions.

Management of Household Energy Conservation

As has already been mentioned, there is no firm policy on management of household energy conservation in Fiji, but the Government, through the Department of Energy, encourages and gives full support on any activities regarding household energy conservation.

I would like at this point to highlight measures taken by the Department of Energy in addressing household energy issues in Fiji. The incentive behind DOE's drive is the subsequent conservation of the energy use of the individual households without lifestyle changes.

The Department of Energy and the Fiji Electricity Authority are conducting a domestic end-use survey in the Labasa grid area. The results of this survey will be instrumental in the consideration of long term domestic energy conservation policy. The direct question of installing more capacity or direct energy conservation measures will probably have to be faced in the next 4-5 years.

In grid connected households a similar line taken on large government premises and industries in reducing electricity consumption has been adopted. The Department of Energy is committing itself to advising the members of the public on how to use electrical appliances efficiently and at the same time recommending proven energy saving equipment.

Woodstoves

Wood is the main source of household energy not only because it has been plentiful in most areas but also because it is usually free. This is particularly true in the rural areas where in most cases it is the main source of energy. Over 90% (Siwatibau 1981) of the rural population use wood for cooking and a large majority still practices the open-fire cooking which is wasteful and inefficient. This wasteful and inefficient process has to a great extent exacerbated the depletion of fuelwood supply available around the village.

Our energy conservation measures are, thus, concentrated in improving the efficiency of woodstoves. Past woodstove programmes in Fiji, particularly the jalef stove, have not been very successful. Earlier on, we had a more detailed look at the problems and lessons learnt. With funding from PEDP and now GTZ our Fiji Woodstove Working Group is evaluating, through both laboratory and field tests, a wide range of stoves, chimneys etc. Surveys of the different ecological zones and ethnic groups will be conducted. The purpose of this is to identify suitable stove(s) appropriate to the requirements of the users.

GTZ funding is to the USP, a regional body. The woodstove working group actively seeks co-operation with other groups in the region. If any of the countries represented here are interested in any of the results or indeed would like stoves tested we would welcome this co-operation.

Renewables

The Department of Energy has substantial plans towards harnessing renewable sources of energy in Fiji. It is currently involved in an intensive programme of demonstration of energy technologies for specific use in the rural areas. One of the main aims of this demonstration is to prove that they can best be utilized for power generation. This will eventually reduce the dependance on diesel power generation which is now being promoted by government as a means of providing electricity to the rural areas.

With the help of the Chinese Government, a 100 kW hydro power project has recently been completed serving three villages in the interior of Viti Levu. A second Chinese mini hydro project, in Vanua Levu, to serve the township of Savusavu and its environmental area is in its advance stage of construction. Both these projects will benefit the rural population in terms of improved energy supply.

Given the rugged terrain and reasonably high rainfall, most of Fiji Islands have the potential for site for mini hydro schemes. The following table gives the present situation of the development of mini hydro schemes in Fiji.

Islands	No of Potential Schemes	Capacity (kW)	Capacity Developed (kW)
Viti Levu	36	2070	120
Vanua Levu	30	5127	800
Taveuni	6	895	250
Koro	2	90	-
Gau	1	55	-
Total	75	8237	1170

Source: Department of Energy

The Department of Energy has initiated a number of PV lighting pilot projects over the last 8 years. A total of 330 individual installations consisting of a basic unit of a panel, battery, controller, and 2 fluorescent lights have been installed in five villages. A substantial number of single installations have been mounted in health centers and boarding schools.

After 8 years of experience the DOE has high hope that PV is a suitable alternative to diesel RE schemes given the high cost of imported fuels and the heavy government subsidy. PV is becoming cheaper and diesel is likely to become very expensive.

Substantial work has been carried out towards making PV an attractive energy option in rural areas. Apart from component testing, training workshops for PV rural technicians have been conducted under the auspices of DOE and CATD. The training was conducted in two phases. The first training, conducted by SPIRE was a training for trainers. This course was designed to enable trainers to successfully conduct their own training courses. The second part of the training had the participants of the first course training rural technicians. The courses were very successful and were made possible by the generous funding of the Government of Japan.

The Department of Energy is just commencing a long term wind monitoring programme to assess the potential of large scale wind power generation. On the same line it is also planning to carry out an assessment of the potential for wave energy.

Educational Programme

The energy conservation education programme involved the production and distribution of energy conservation information stickers, cartoons in the daily newspapers and leaflets dealing with application of new energy conservation technologies and processes.

Conclusions and Recommendations

I would like to conclude by highlighting a few issues which are crucial to the overall planning of the rural energy sector. Household energy constitutes an economic sector. With its relationship to social welfare and quality of life, the household energy sector should be viewed as a priority not solely from policy-making but also from research, planning and investment point of view. I need to stress here that these are personal views and should not be in anyway construed as official.

(a) The task of collecting energy information in the right form at the right time has been made difficult by the absence of a systematic information gathering amongst government and non-government organizations involved in developments in the rural areas. It is imperative that such a system be established.

(b) Information about rural energy resources, use trends, consumption and the myriad of relevant data important in realistically working out solutions should be readily available. In this regard, the Department of Energy must be responsible for an information system whereby departmental energy related information are coordinated. Of importance here is the continuity of information gathering.

(c) We have to remind ourselves that wood will still continue to be the main source of energy in the rural areas. We, therefore, have to devise conservation measures for the resources available. Rational management of fuelwood based on sound natural resources and land utilization concept is mandatory. The high energy future with high prices in commercial fuels will certainly increase relative and absolute demand for wood fuels.

(d) Work on alternative energy resources should be intensified. Hydroelectricity potential in Fiji is quite high. Other options such as small hydro, solar, wave and wind power could prove to be the best option in attending to rural household energy needs.

(e) Lastly, there should be a clear policy on rural household energy. This will ensure better management of household energy.

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X. HOUSEHOLD ENERGY, WOMEN AND THE ENVIRONMENT

ENERGY, ENVIRONMENT AND PACIFIC ISLANDS HOUSEHOLDS

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Energy Development and Environmental Change

Energy has of course always been a fundamental part of the life of every Pacific island household. Fuelwood and the fragrant light of resin candles alone can however do little to promote social and economic development. Today a wide range of energy options is available in support of the avowed objective of all island governments to improve life and economic productivity. The removal of too much fuelwood in the distant past at times may have caused localized environmental problems. Today, the different nature and much bigger scale of energy projects always raise the possibility of environmental costs. Though households are assumed to be beneficiaries of energy development projects they sometimes are forced to bear those costs.

As with any development activity the production and distribution of energy involves some manipulation of the natural environment, giving rise to change. Change is not necessarily bad. And, even where some adverse environmental change does result this is sometimes in circumstances where long-term socioeconomic benefits outweigh the environmental disbenefits. Unfortunately, it must also be said that far too many energy projects have proceeded on the assumption that the expected economic and social benefits of energy production would outweigh any environmental costs - without any effort having been made to identify and make provision for those costs.

Energy agencies are not well prepared to address the environmental and social dimensions of the projects which they sponsor. This requires additional information and skills, and a capacity for interagency cooperation which is difficult to achieve. In recent years some guidance has been given (eg. PEDP Report REG 89-2: "Guidelines for Environmental Assessment of Energy Development Projects in Small Island Countries"; and Asian Development Bank's "Environmental Guidelines for Selected Industrial and Power Development Projects"). Increasing public and political awareness of the ease with which the environment can be disturbed by development activities places on those involved in energy development a greater responsibility than before to seriously address the wider aspects of such development.

South Pacific households typically have low levels of energy consumption. An increase in material standard of living, coupled with a fast population growth rate for most countries means rising demand for energy and, therefore, greater environmental impact. Energy development activities can affect environment and so disturb households in a variety of ways. Some examples, with explanations of environmental consequences, are provided below.

Fuel Oil Spills and Waste Discharges

Insufficient attention has been paid to prevention and control of fuel oil spills and leaks. Oil products dispersed into the environment decompose very slowly. A power plant manager may believe that small spillages are only a minor and short-term problem. However, he probably doesn't realize that the effects of a series of small spillages builds up, and can eventually give rise to significant pollution outside the boundaries of the plant - often directly impacting households which use the affected waters for bathing, fishing, or perhaps even drinking. Relatively small, but regular, spillages from Honiara's main diesel generating station made quite a mess of the tiny stream which flows from there through that town's central parks and alongside the information center of the Solomon Islands Tourist Authority. The problem was easily avoided. Proof of this can be seen in the relative cleanliness of that stream today - a result of improved management at the generating station.

There will always be oil wastes to be disposed of, even where some recovery is possible. Disposal is something which needs to be carefully considered. Burning of oil wastes at the wrong time and in the wrong manner can produce an air pollution problem. Burial is not necessarily a good solution either, as oil can seep underground and still find its way into streams or groundwater supplies. The same environmental problem can arise where waste oil is sprayed onto roads for dust suppression.

Why, then, is oil such an environmental threat? It forms a very thin "seal" on the surface of water - a seal which prevents gases such as oxygen and carbon dioxide (both very important for the growth and survival of plants and fish in those waterbodies) from passing easily between the water surface and the atmosphere above. Low levels of oil pollution may not kill fish but they will certainly be affected in some way. They may seek to avoid the problem by swimming elsewhere. Yet, "elsewhere" may not be a suitable habitat for them, or it may already be fully populated by other fish. There is, however, another oil population hazard for fish - one which fishermen dread! Where fish swim in oily water they absorb some of that oil and this then imparts to their flesh what is described at a "kerosene taint". Such fish have very unpleasant flavor. Once the customers know that a particular fishing area has produced a tainted fish or two they will avoid fish known to have been taken from anywhere near there, and this is not good for fishermen's sales!

Other sources of pollution are ship to shore transfers, and failures of storage tanks and lines. With even the best possible care and attention spillages will happen. The best possible choices of location (away from environmentally sensitive areas) and of engineering design can do much to minimize the chances of spillages and the extent of the harm which they do. Spillage must, however, be anticipated - by effective planning to keep spillages to an absolute minimum. Good planning also means being prepared to clear up environmental damage, no matter how small. A decision to locate a storage facility at the shore, and to effect ship to shore transfers, implies a recognition that there will be spills, and that a "trade-off" decision has been taken that some alternative actual or potential use of the area (perhaps fisheries, public recreation) has been "traded off" against the public benefits of fuel storage. The public then has to bear the environmental cost of the decision. The management authority should not forget this, and it is the duty of governments to legislate for, and take other appropriate measures to ensure that this cost is kept as low as possible.

Any oil spilled into water must be contained and prevented from spreading. Booms, often made of long inflated plastic tubes, are floated on the water so as to hinder the spread of the polluting surface layer of oil, and to contain it for collection, treatment and onshore disposal. There is a very important environmental consideration here. Special detergents have been formulated to emulsify floating oil so that it will disperse. This quickly removes the visual pollution and helps prevent the formation of tar lumps which can spoil beaches. However, these detergents can be harmful to some marine organisms, especially shellfish, and even kill them. The cleanup, then, may involve a "trade-off" between fisheries and recreational interests. Petrol spills are not treated with detergent. Fortunately, petrol vaporizes and is dispersed into the atmosphere, quickly easing the pollution problem. [illegible]te is more of a problem; heavy residual oils the most troublesome.

The tanks of petroleum tankers need to be cleaned from time to time. This was once a major source of marine oil pollution as tanker masters took the easy option and cleaned out while underway and out of sight of land - whether in national or international waters. Strict regulations under the International Maritime Organization have curbed much of this form of abuse of the seas. It still may happen, however, where surveillance of shipping is weak, as in the South Pacific.

A greater problem is currently posed by interisland shipping within island nations. Though beyond the control of energy authorities it should be noted as a matter which adversely impacts coastal households dependent on seafood for subsistence and for commercial activities. The problem arises from the oily wastes of ships' bilge water dumped in inshore waters - sometimes, even inside lagoons.

In establishing a storage facility, consideration should be given to the possibility of including the infrastructure required for controlled tanker cleaning. This would mean installing tanks to contain the wastes, and provisions for treating and disposing of them. It should not be forgotten that, as with all shipping, there are also operational oil wastes sewage, and garbage. These matters should all be considered, even if it is only for the purpose of drawing the attention of local port authorities to the need to use their powers and resources to address the problem.

Tanks used for storage of petroleum products sometimes need to be cleaned. The sludges which are removed from the bottom of these tanks are always potential problems for the environment. Careful arrangements for their disposal must be decided and included in the waste management procedures. The environmental hazard posed by these wastes is made worse where the sludge contains residues from leaded petrol. Close cooperation with health authorities is necessary to ensure that lead does not become an environmental contaminant. This metal has a distressing effect on children in particular. Among other things, where they absorb lead - not only from carelessly discarded tank cleaning wastes but, in households close to busy roads, also from inhalation of vehicle exhaust fumes - their intelligence is affected and this is revealed by reduced learning ability.

Allowance must also be made for dealing with wastes from inadvertent leakage. Simple earth bunds are usually provided at fuel storage sites, but plans seldom exist for the treatment and disposal of wastes held back by these bunds. If not quickly removed these wastes will infiltrate the ground, and nearby groundwater supplies may become contaminated. Or as the people of Betio, Kiribati, may one day discover - seepage of diesel fuel and petrol from deteriorating storage tanks through the beach could make shellfish and fish in the adjacent lagoon inedible.

Regular and proper maintenance of storage tanks is a matter of great importance for environmental protection and public safety. Unfortunately, there are more than a few government-owned tanks in Pacific Island countries which are dangerous from lack of maintenance - "accidents waiting to happen".

Cooling Water From Thermal Power Plants

Cooling water can kill. Single pass non-recirculating cooling water systems require huge volumes of water. After Use, this water is hot and contaminated. Its dispersal into the environment is the potential cause of serious problems:

(a) by altering the salinity (saltiness) of seawater;

(b) by increasing the temperature of the stream or coastal water into which it is disposed; and

(c) by introducing into those waters chemicals which can be poisonous for animals, plants and humans.

The corals of Pacific island shores are very common but most species of coral can live only in water which is as saline (salty) as seawater. They may be able to survive the disturbance caused by occasional natural flooding, but only for short periods. Where they are exposed to freshwater for extended periods they will die. For many Pacific islands households these coral-reef based fisheries are vital. Corals are more than just nice to look at. Together with the many plants and animals which grow only in association with them, they form the basis of complicated ecological systems which sustain important coastal fisheries. Corals, in growing, leave in place hard limestone skeletons which become the body of the reef - dead, but serving a vital role in protecting island coasts from erosion.

Corals are particularly vulnerable to the effects of heated water. About 30 degrees (Celsius) is as much as they can tolerate, for short periods. Summer freshwater temperatures in many areas of the Pacific island region are close to 30 degrees already. Only a small amount of heated waste cooling water is required, then, to increase the water temperature of a lagoon to a level which will kill corals.

Chemicals must be added to cooling water to inhibit corrosion and to prevent contaminating growths of algae. A proportion of these chemicals will be discharged into the receiving waters adjacent to a thermal power plant, and these could include potentially dangerous metals such as chromium. In one of its chemical forms (hexavalent), it is very poisonous to animals, fish and people. To protect island households there should be a ban on the use of this chemical for control of contaminating algae.

Changed Stream Flows

The runoff of water from a catchment and its flow along streambeds over time establishes something of a natural pattern. Seasonal variations of rainfall result in lower or higher flows. On average, however, there is some regularity in the process of stream flow and the movement of sediments (stones, gravel and sand) in those streams. The animal and plant communities of the stream water adjust to these variations. A very unusual event like a massive flood or a very large landslip can sometimes disrupt this pattern, but nature does, in time, adjust.

Since a hydropower scheme removes water from a streambed, a portion of that streambed between the inlet and the tailrace below the turbine will no longer function as a stream except intermittently, at times when water which is surplus to power generation needs is released. This is very unlikely to fit any natural pattern and so inevitably is a cause of environmental disturbance. This is an environmental cost which is usually accepted when decisions are taken on such projects. However, such decisions should be taken with a view to easing the disruption to stream flow through project design measures and through operational guidelines.

In most hydropower schemes the water will be returned to the same stream. Flow downstream of the turbine remains, in the total, much the same. For hydro schemes in which water is stored behind a dam for periodic on-peak power generation, however, the flow pattern inevitably changes, since the primary determinant of downstream flow will be the demand for water for power generation. This overriding priority for power, unless curbed by other considerations, can in some cases cause serious direct and indirect environmental costs which must be borne by downstream households. For instance, a coastal community which depends on groundwater supplies may suffer from saltwater contamination of these supplies if dry season stream flows are held by a dam, groundwater recharge is slowed and seawater diffuses further upstream and into that groundwater.

<u>Sediment</u>

Sediment is soil material washed from the land and into streams and the sea. It reduces the level of sunlight passing through water, so reducing the growth of aquatic plants - and it also interferes with feeding by many of the animals there, including corals. Environmental problems of sedimentation, often causing a reduction in fisheries potential, can easily arise during site clearance and construction activities. Sedimentation problems also develop in the course of dredging for reclamation of coastal sites, or where a seabed trench is being excavated for the laying of a fuel pipeline.

Corals feed on tiny particles of food brought to them by wave action and currents. These same physical processes also distribute any sediment which may be in the water. Sediment is not food for corals. It is indigestible, and abrasive, and damages the fragile coral polyp animals which are the living parts of corals. Coral polyps are able to avoid some of the damage that settling sediment can cause to them - by closing up. When they do this, however, they do not feed. They cannot remain closed for long. Unfed, they weaken, and eventually die.

In order to minimize environmental damage from sediment pollution during site clearance, construction and or plant operation it is necessary to adopt specific measures to reduce soil disturbance, and to prevent water containing sediment from draining from a project site into streams or the sea.

<u>Battery Wastes</u>

Batteries are a widely used source of energy which rarely is considered for its environmental impact. Of particular concern are those which contain lead. The point has been made, above that lead poisoning is a particularly distressing and intellectually disabling problem where children are concerned. Yet it is not uncommon to see the broken lead plates of discarded batteries lying about in playing areas. Overall, the level of Pacific islanders understanding of technical issues is not great. Very few people are likely to be aware of lead hazards. Overstretched health agencies are not dealing with the educational need in this respect. It is not unreasonable to suggest that the agencies promoting and controlling energy use should assume a responsibility to educate the public about this and other energy-linked health issues.

Biomass Projects

Tree plantations for fuelwood are very different in composition and structure from natural forests and they interact differently with the environment. For one thing, rain passes more quickly through a plantation forest and this means that less groundwater will be held in the soil for slow release during drier periods, not only to the plantation itself but also to natural and cultivated plants in adjacent areas. The groundwater table can be expected to drop and, consequently, streams in the area are likely to experience a reduction of flow. Furthe: ·ince tree plantations take up sizeable areas of land, in land-short countries a fuelwood plantat' · ıy seriously restrict other land use options, even though these may be economically and enviro...nentally more attractive and/or appear to be socially more appropriate. The apparent benefits of a biomass energy project which displaces farm households or reduces agricultural opportunities for the additional households of a fast growing population could quickly be overwhelmed by the social costs of shortages of arable land.

Pollution from fertilizer applied to plantation tree crops is another possible environmental cost. Only a portion of chemical fertilizer is taken up from the soil and used by the fuelwood crop for growth. A significant proportion of applied fertilizer is washed from the soil by rainfall. This not only represents an economic loss for the biomass project, it may translate into a cost for someone else - through a form of environmental pollution where the fertility of streams and coastal waters is suddenly increased. Such a change can dramatically alter the situation to which fish and shellfish have long been adapted. Mangroves may benefit, using the opportunity for increased growth. However, fish may leave the area or, at worst, suffer from sudden death from lack of oxygen - in cases where small water plants and algae use the fertilizer for unusually rapid growth. As these plants and algae die the level of oxygen in the water drops dramatically, and fish may die as a result. Stream side and coastal households are among the losers in such circumstances.

For an example of another kind of environmental cost that may arise with energy projects, consider the case of charcoal production in the Shortland Islands of the Solomon Islands. In the course of an "appropriate technology" workshop, a community was introduced to the concept of charcoal as a more efficient fuel source. They liked the idea, and proceeded to use coconut plantation waste for charcoal manufacture. Life in the kitchens was improved, but those responsible for fuelling the hot air copra drier with coconut wastes had lost their fuel source. They found another - the nearby stands of mangrove, which produce a superior fuelwood. But this happens to be a fishing community, and a crucial element in fisheries production in the area is the mangrove ecosystem. The air in the kitchens may be cleaner, but at the cost of a drop in fisheries production, requiring more effort to catch fish for home consumption and a reduced surplus for sale. The quality of life for these households dropped as a result of this intervention - but, in this case, was restored once the novelty of charcoal had passed!

Energy, Environment and Resources of Village Households - A Case Study

The various aspects of energy-environment linkages as they affect village households can be illustrated through a "case study". In the South Pacific there is considerable variation in circumstances between and within villages. Those of Marovo, in the western Solomon Islands - the subject of this "case study" example - are relatively resource rich. They have excellent fisheries resources in a complex of reefs set in a very large lagoon whose outer limits are defined by long barrier reefs. Several sizeable rivers flow into mangrove fringed estuaries within the lagoon and these are a very important fish habitat. Though much coastal forest has been cleared for agriculture and for village settlements there remain extensive, easily accessible tracts of tropical rainforest.

As well as providing food, the lagoon serves as a complex of "roads". There are no roads on the land encompassing Marovo Lagoon. Transport between villages and to clinics and other services is by paddled or outboard motor powered canoes. In Marovo, distances are measured in "gallons of fuel" - with an additional gallon or two added for bad weather travel. Travel to the national capital, Honiara, or to the Provincial capital, Gizo, is also by water transport - interisland boats which transit the lagoon en route to or from these two centers. For these reasons, and for its cultural associations, the lagoon is the focus of the existence of the people of Marovo.

A household energy consumption survey of this area was made in 1987 (PEDP Report SI 88-2). One hundred and twenty-five households in seven villages were surveyed; roughly 20-25% of the total population of the area. The significance of energy for these coastal villages is obvious from the results. Twenty-four percent of households owned one or more outboard motors; and 32% of households had canoes which could utilize such a motor. Use of batteries averaged 2.6 per households per week. Kerosene constitute the main source of energy for lighting, while locally produced firewood is used for cooking and for the drying of copra, a major cash crop.

The general standard of health of the people of Marovo is good, owing to a ready supply of home-grown and captured foods. Since levels of cash income in the area are very low (the PEDP survey arrived at a tentative average figure of $980 per households per annum; equivalent, at that time, to about $US490) it is obvious to all that the high quality of environment which produces these foods must be maintained. This need is reinforced by the PEDP finding that of the very low cash income of Marovo households more than half is spent on purchases of energy.

Even though such a very high figure for the proportion of cash income spent on commercial sources of energy might not always prevail (the survey was at a particular point in time and that happened to be a period of very low levels of income from copra) there is no doubt that it always is a major element of the cash cost of living in this area. And this is a point that could be made for many coastal village households in the South Pacific.

The PEDP survey revealed that firewood for cooking was primarily from dead trees which otherwise would not be used; trees felled in the course of clearing for agriculture, for instance. Cooking needs therefore appear not to be significantly depleting the area's forest resource capital. Even so, 58% of households respondents were of the view that they would face a scarcity of firewood within five years. In the case of firewood used in the drying of copra the environmental impact must be considerable. Ninety percent was said to come from living trees and these were mainly mangroves, which are of vital importance in sustaining inshore fisheries production. Forty-seven percent of respondents anticipated a shortage of firewood for copra drying within five years. In assessing these indications of Marovo people's perceptions of future scarcity it is important to note that limits may be approached even sooner than they realize. The Marovo population is currently expanding at a rate of 3.7%, which represents a doubling in less than 20 years.

The fisheries richness of Marovo Lagoon has attracted the attention of the skipjack turn industry - for the tuna baitfish which the Marovo environment produces in quality and quantity. Currently, 60% of the total tuna baitfish catch of the Solomon Islands is taken from

Marovo Lagoon. During the long tuna fishing season, small baitfish "essa" boats criss-cross the lagoon setting nets for the baitfish, which are collected by larger tuna catcher boats.

Outboard motor powered canoes, interisland passenger and cargo vessels, and the incessant presence of the vessels of the industrial tuna fishery, mean that the lagoon which Marovo people so value is not subject to oil pollution - primarily from the pumping out of boats' bilgewater. For a fishery oriented community, in an area where tourism is being developed this a most disturbing development.

Energy linkages with the environment are wide, and can be decisive. Consider the Marovo case further. The lagoon environment is beginning to deteriorate from careless handling of an energy product. Mangrove forests along the shoreline are being depleted to provide firewood for copra drying. Both activities have direct adverse effects on fisheries production, and present indications are that the situation will continue to worsen. The area is of interest to mineral mining and to tree mining interests (the latter usually referred to as "logging"). If either type of development eventuates in the area the lagoon will be under further threat - from sediment pollution and from mineral processing chemicals.

The people of Marovo do, of course, derive social and economic benefit from some applications of energy in their area; notably in the area of transport. Yet while they are quite mobile, circumstances are such that commercial sources of energy have contributed relatively little to improvements in the household environment. Lighting, for instance, is exceptionally poor. This fact alone inhibits social advancement by imposing a crippling constraint on reading, writing and studying. The area has no significant hydro potential, apart from a couple of sites where microhydro schemes could be developed, with insignificant environmental impact. There is just not the required concentration of population to achieve economies of scale. Under such circumstances, rural electrification becomes a very expensive ambition. How then, can the households of island communities such as those of Marovo obtain the modest advances in energy use needed to assist them to achieve the sort of sustainable development which they seek? Is the energy and infrastructure "spinoff" from mining, with its major social and environmental upheavals, the only option?

Energy Policy and the Environment

As is the case with other sectors of "development", energy development has had a narrow economic and engineering base. Despite a global trend towards a broadening of development policy to include assessment of environmental consequences, in the South Pacific, relatively little consideration has been given to environmental implications in general or to the environmental consequences for households. The word "environment" is used here in a pragmatic way which best suits Pacific islanders' perceptions - so as to include the natural resources such as soils, forests and fish which are products of the environment.

Some governments have set environment-related policy objectives concerned with, for example, rural electrification, and energy conservation. Rarely has the former been considered in terms of the totality of the household environment, with a view to making the most effective contribution to its improvement. Since the region imports its commercial energy sources in the form of Petroleum products, energy conservation has been directed to conservation of foreign exchange rather than to conservation of resources. Nor has there been a great deal of activity in environmental assessment of energy projects. Accordingly, there is little experience in the region in the formulation and implementation of environmental policy for energy development. The need is apparent, and awareness is growing. Some examples of how energy policy can affect environment, directly and indirectly, are outlined below.

Environmental Impacts of Energy Projects

Early forms of environmental assessment, still in place throughout the world, consider only the affects which an already designed (according to technical and economic criteria) energy project has on the environment. This form of assessment is termed "environmental impact assessment", of E.I.A. Often, E.I.A. has produced findings which, if taken into account, could have made a positive contribution to project design and performance. Too often, however, there has been little opportunity to incorporate new ideas, the project having been decided in advance of the assessment. Where Pacific Island agencies are developing a policy to account for environmental aspects of energy development it is important that they should embrace full environmental assessment, focussing on anticipation and on prevention of environmental difficulties rather than simply addressing end effects.

The use of poisonous substances in energy production is a matter which needs to be carefully addressed. There are sound health reasons for this, but there is also an acute political sensitivity in the region to any prospect of contamination of the sea. Chromium is an example. This was earlier identified as something which effectively kills contaminating algae in cooling water systems, but at a potential public cost through contamination of marine foods. Policy should provide a ban on such a chemical.

A bizarre form of energy production has been promoted in the island region by American interest in recent years - the so-called "co-generation" of electricity from the incineration of hazardous wastes. Even though technically unwise and though such activity could have dreadful environmental results there are still some island leaders vulnerable to the financial inducements being offered by the unprincipled pushers of this type of venture. It is much easier to deal with this matter with anticipatory policy which excludes such environmentally dangerous activity rather than be forced to fight off each attempt; action made professionally hazardous by the involvement of influential persons.

Environmental Consequences of Pricing Policies

Pricing policies, too, may affect the environment. An example serves to illustrate this point and to show how far reaching and unexpected may be the results of a decision on pricing.

It is possible to envisage circumstances where, in support of rural development policy, a decision is taken to subsidize fuel for outboard motors - vital for transport and fishing in parts of the Pacific. In such a situation, an important environmental consequence could well be that fisheries resources are used differently. Not all rural households have the financial resources to purchase outboard motors or, having purchased them, to use them while fuel prices are high. A subsidy could lead to increased fishing effort. This could have good results in terms of improved diet from higher households intake of marine foods. Or fish catches for sale might increase, bringing increased household income. In some circumstances, of course, the increased fishing pressure might be such as to cause a decline in an already heavily fished area. On the other hand an unanticipated social benefit might be obtained - where those with outboard motors take advantage of subsidized fuel to fish afield, leaving the fisheries resources nearer to shore to those whose canoes are still powered by paddles. The environmental ramifications of decisions on pricing may be many and varied.

Environment, and Energy Project Design

There is now a global trend towards redefining development in terms of sustainability. This implies closer attention to the long-term quality of development, rather than the relatively short-term quantitative focus that has characterized much development up to now. Sustainability is to be addressed in economic, social and environmental terms. As with other sectors of development, those responsible for energy matters are faced with a need to give careful consideration to what sustainability means and how it is to be achieved in their sectoral context. While the maintenance of good environmental conditions is a key aspect of sustainability there are also related social considerations. Equity - a fair distribution of, and access to, resources, and rights to a decent environment are important considerations. This includes the rights of those yet to be born, to benefit from these resources and their environment. Properly implemented, this fresh approach will drastically change the current emphasis on short-term economic considerations.

Even before island governments formally adopt this new approach they will find that their energy projects are being shaped along these lines - since Aid agencies increasingly are assessing recipient country requests in terms of sustainability.

One of the environmental considerations which will arise as part of the debate on sustainability in the energy sector, is how to minimize environmental disruption and repair whatever environmental damage arises in the course of energy production and distribution. Earlier in this paper a number of examples of adverse effects of energy activities on fisheries has been provided. The general setting of energy projects will, in future, require close consideration. Hydropower project proposals, for instance, will need to be examined more thoroughly in terms of the function of the whole water catchment and on other uses of that catchment, both upstream and downstream.

Even before the concept of sustainability is fully developed it can be expected to bring benefits to energy project design. The traditional approach to project design is one which confines a project within boundaries of time, space and sector, and which rewards project planners and managers on the basis of how well they perform within these boundaries. Only relatively short time periods are considered. Monitoring of project performance is limited to these short periods. There is rarely an examination of long-term benefits; an assessment of whether the project's benefits are <u>sustained</u> in the long-term. Usually only a limited area of project activity is considered - the site of a fuel storage area but not the adjacent land and sea, or a hydropower dam site is studied in detail while the characteristics of the associated water catchment are only superficially examined. And, while sectoral planning may be tidier and easier, its narrow, energy-focussed view means that much information and understanding arising from "non-energy" sectors that has potential for improving project design and sustainability cannot be used. Nor are the standard "central planning" institutions of Pacific Island Government able to handle this breadth of planning and project design. What is needed is a focus on sustainability of the results of a project, rather than one the project itself.

If the sustainability of project benefits is to be seriously considered, then project design will need to internalize what have previously been treated as project externalities; deal explicitly with continuity of project benefits beyond formal project life; monitor all aspects of project performance and deal firmly with any negative results in terms not only of the project itself, but also of areas beyond the project. It will also be necessary to address and consider how positive results of a project can be extended to bring benefits to areas beyond those of the project.

Concern About Carbon Dioxide Emissions

Industrialized countries have imposed a heavy burden of environmental uncertainty on Pacific Island households through release of carbon dioxide - much of it arising in the course of power generation - to the global atmosphere. Kiribati households wonder whether their island home will become untenable as sea level rises. Elsewhere on the island region there is a developing awareness of the prospect of increased crop pest and disease damage of crops currently grown in some areas, becoming inviable as temperatures rise and rainfall patterns change.

There may be relatively little that Pacific Island energy planners can do to contribute directly to the required solutions. The issue is a dramatic expression of the inevitability of the energy sector's links with the environment and should be regarded as a sign that future applications of energy for development require the comprehensive approach of sustainability if these are to truly benefit the people of the Pacific Island region.

WOMEN'S CONCERNS AND SOCIAL EFFICIENCY IN RURAL AND HOUSEHOLD ENERGY POLICIES

Mrs. Suliana Siwatibau
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In my presentation I wish to:

(a) first, place the energy issues under consideration in terms of the overall development goals of our countries;

(b) second, clarify what I mean by the terms "rural energy" and "household energy";

(c) third, introduce the concept of "social efficiency" under which I shall discuss the role of people, particularly of women in the areas of rural and household energy;

(d) fourth, discuss how the concerns of women can be taken as inputs into formulation of national energy policies and programmes.

Energy is one of the most basic inputs or raw materials for development. I would therefore like to begin by examining briefly the development goals our countries in the Pacific have set for themselves.

The five most commonly expressed national goals in order of frequency are:

(a) Increasing equity in the distribution of development resources and benefits, particularly between urban and rural sectors.

(b) Achievement of greater self-reliance.

(c) Development of human resources and meeting basic human needs.

(d) Sustained economic growth.

(e) Development of national unity, identity and political stability.

One will note from the list that equity, particularly through promotion of rural development, is the most commonly expressed concern of our countries. Appropriate rural energy provisions, therefore, to service rural development, would appear to be a priority for consideration. It is important, in this context, that planning for rural energy be integrated into and service each country's rural development plan. Unfortunately, there can be temptation to plan rural energy systems separately from other plans for rural development. For example, an energy policy promoting PVC lighting as a priority could miss opportunities for small grid electrification that could stimulate rural industries in areas where other non-energy sectors have programmes with energy sources that could be utilized concurrently for electricity generation. A public health project to supply water to a rural location may provide an opportunity to utilize the system for hydro electric generation. An Agriculture Department's programme for irrigation through large diesel pumps, or a Fisheries Department's plan for establishment of local ice-making facilities with expanding fisheries projects again offer opportunities for electrification for other purposes.

The other common development goal of relevance to this seminar's deliberations is the desire to meet the basic human needs of our peoples. This includes the provision of sufficient energy to meet the basic household energy need for cooking.

To establish the basis of our discussion, I now wish to define what I mean by "rural energy" and by "household energy".

The term "rural energy" has been interpreted in two ways:- Some people use "rural energy" to typify a class of energy systems mostly comprising small scale renewable energy sources such as micro-hydro systems, PVC lighting, wood burning stoves, small scale biomass systems, and small wind energy systems. Small diesel systems, though non-renewable are often also included. Under this definition non-industrial wood-burning stoves and charcoal stoves, which are used in urban areas would be considered rural.

Others use "rural energy" in a broader sense to describe energy systems utilized in rural locations as geographically defined. In this paper, I am using "rural energy" defined according to geographical location rather than as a typology of energy systems. Under this definition, "rural energy" includes energy sources found in rural areas, energy supplies utilized for rural areas, and energy demand in rural areas. I would follow the demarkation of rural areas in each country as determined by the Census Office.

The term "household energy" includes all energy supply and use to fulfill the needs of dwellings such as family homes and hostels. These are mainly for cooking, lighting, refrigeration, water-heating, air-conditioning and other small electric appliances. For most of our Pacific households, only the energy demands for cooking and lighting are important.

What is the role of people, particularly women, in rural energy and in household energy?

One of the most important considerations that planners and policy formulators take into account in terms of energy planning, is efficiency. This is usually a measurement of how much output one derives from processing a given input. When making choices about energy systems, they usually consider economic efficiency and energy efficiency. Normally economic considerations far outweigh energetic considerations, for if the costs are too high, energetic efficiency is definitely usually set aside. Even our own everyday choices of energy use are usually rationally based upon economic criteria. For example, although it may be energetically more efficient to cook with a kerosene primus or LPG gas cooker, most housewives in urban Fiji, who have those cookers, still cook many meals through the much less efficient open-wood-fire because it is cheaper. Table 1 shows the average cost of cooking a meal for an average-size family using the different cookers utilized in urban Fiji. These prices are those existent in 1981 in Suva.

Normally, each project planned is assessed for economic viability, and some note is taken of, and if possible attempts are made for improving, its energetic efficiency. Indices have been developed for these two properties of projects. For economic efficiency, a cost benefit analysis

Table 1: Relative Costs and Total Energy Expended

For Different Cooking Modes in Urban Suva's Households Surveyed in 1981

Cooking Fuel Used	Cost/meal/person	Total MJ/meal/person
Wood in Open Fire	Up to 0.3c	7.35
Wood in Stove	Up to 0.3c	6.3
Kerosene (Average of all cookers)	2.3c	2.55
LPG	29.75c	2.63
Electricity	55.05	2.41

is made and the discounted benefits weighed against the discounted costs. For energy efficiency two indices may be used:

(a) a conservation efficiency index which weighs the actual useful energy output against the total energy input; and

(b) an entopic efficiency index which is a measure of the degree of matching, between the quality of energy provided and the quality of energy required to fulfill a particular task. For example, a high quality energy source, such as natural gas, which can produce very high flame temperatures of up to 2,000 C when used for low quality heat, such as for cooking (100 C - 400 C) or for domestic hot water heating (about 60 C) demonstrates low entopic efficiency.

While considerations of these economic and energy indices may be sufficient for large scale, conventional energy systems, I would like to suggest that they are definitely inadequate for the rural and household energy sectors. In these sectors, a third index or measurement of "social efficiency" is necessary. One of the main reasons that so many rural energy projects throughout the world and the Pacific, have floundered is because the planners and decision makers neglect to take people's status, behavior, and priorities into account. In terms of household energy, the views of women, the chief managers of households, must be taken into account not only in the implementation, but also in the formulation and planning of projects.

Decisions for energy policies and programmes are taken at different levels, as shown in Figure 1. Policies are formulated after careful considerations and analysis of the different sub-sectors of the energy sector as shown in Figure 2. In terms of decision-making people become most involved at the level of projects (Figure 1) and as household energy consumers (Figure 2). People's priorities and behavior tend to have much greater impacts on small-scale rural energy systems and on household energy consumption; than on the other energy sub-sectors. I believe that there are three main influences on energy choices and use -consumers' behavior, government policies (e.g. pricing structures) and technology. The relative importance of these three influences on the different sub-sectors, I have tried to represent in Table 2.

Figure 1: Suggested Arrangements for Involving Women at Different Levels of Decision Making

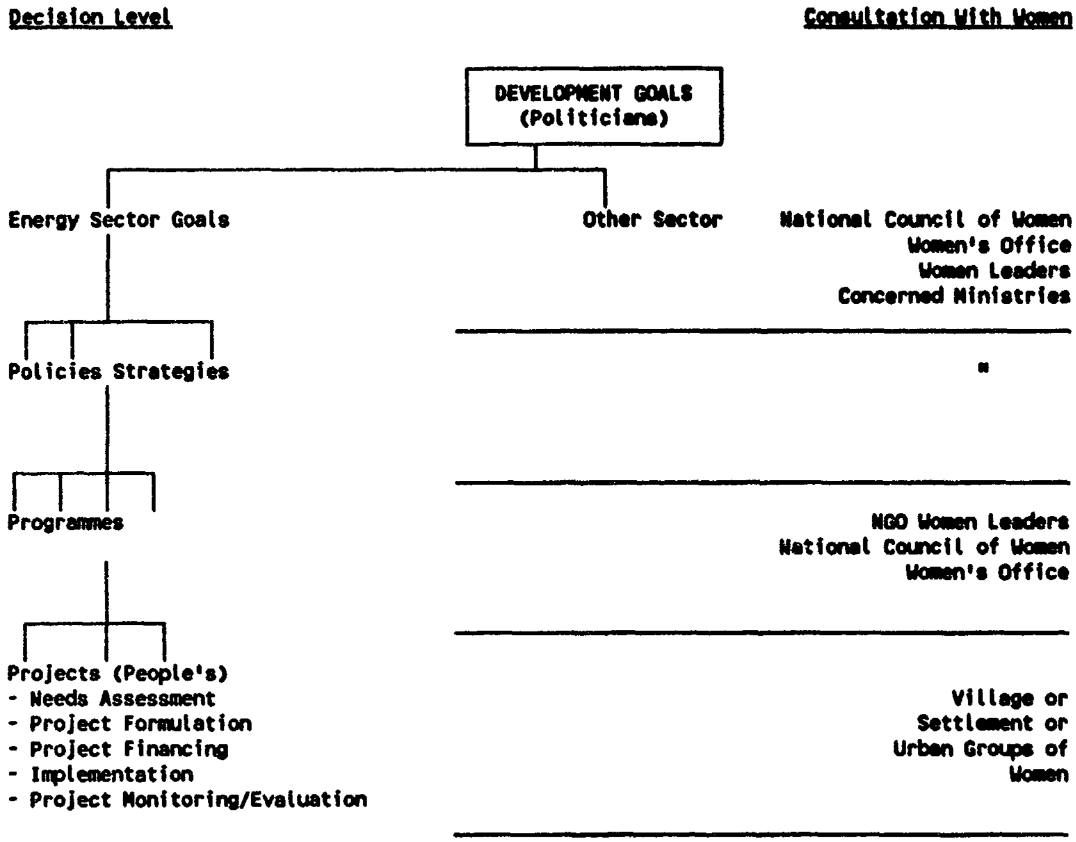


Figure 2: Energy Sub-sectors for Policy Considerations

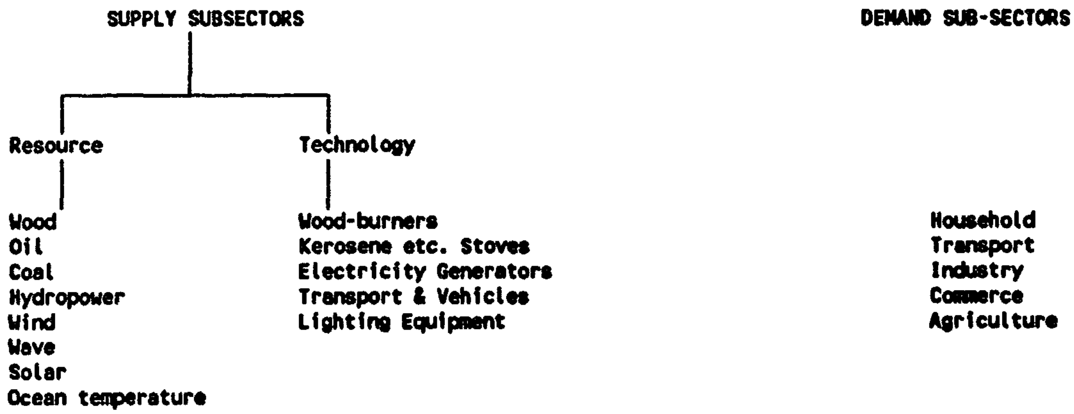


Table 2: Relative Contribution of Three Major Factors, Energy Choices and Use in the Different Sub-sectors

Sub-section	People's/consumers' Priorities & Behavior	Government Policies	Technology Changes
Household	xxx	xx	xx
Rural energy	xxx	xx	xx
Industries	0	x	xxx
Transport	xx	x	xx
Commerce	x	x	xx
Agriculture	xx	x	xx

Key: XXX Important XX Sometimes Important X Rarely Important

In terms of rural and household energy, it makes sense to study people's priorities and behavior and incorporate these efficiently in the provision of energy services to meet their needs. This is what I am calling social efficiency.

Social efficiency would be enhanced if people were involved at every step of decision-making, particularly at the project level. Developing a small wind farm or a mini-hydro requires the reservation of tracts of land. Landowners must be consulted. Women should be included in such consultations, as in many countries they are the main tillers of the land and gatherers from forests. In our matriarchal societies, women will of course be consulted, but in the patriarchal ones, special efforts must be made. Building a wood-burning stove for a boarding school, may require setting land aside for fuelwood or may require restoring villagers to supply wood. Again people will need to be closely involved in all stages of decision-making. Once people are involved in a new endeavour, their daily routine of work has to be adjusted and their various roles in the community varied or extended. It is most important to understand first what different members of the community do (that is men, women, youth, children) before a new project is introduced to ensure the project utilizes their current organizational structures and task divisions efficiently. Even in the area of household energy, where it is assumed women's role is paramount, the role of men cannot be entirely neglected.

Let me illustrate with an example from Fiji. The Fijian authorities, have for over half a century now, been concerned with improving the conditions of cooking for women. Long before our Energy Department was established, enthusiastic Public Health Officers used to inspect villages, talk to the whole community, and persuaded them to build kitchens with broad chimneys over raised open-fire places as a health measure. They were able to do this because men and women were involved in the discussions and men built the kitchens according to agreed designs.

After independence in 1970, rural administration was re-organized and regular village inspection visits ceased. Women's Interest Officers took over responsibility for household hygiene, including kitchen cleanliness, from the public health department. They introduced wood burning stoves through women's groups. After its establishment, the Fiji Department of Energy also developed its own stove design. Although the department, through an NGO rural training center, had taught men to build this new stove, its introduction into villages remained in the hands of women's groups.

A survey by the Department of Energy in 1985/86 showed that the great majority of stoves were either left unused or had been abandoned after a short period of use. Some had never been installed and lay beneath weeds outside dwellings. This was true outside Fiji as well. In Tonga, I found one such stove being used as a door-step. At least it was being put to some use.

The reasons for this sad state are many. One of the more common ones given was the lack of a proper kitchen to fit such a stove in. Kitchens are built by men, and men were either not free or could not be persuaded to build appropriate ones.

Nevertheless, there have been cases of success. Notable among these were those where women and men together discussed the introduction of wood-burning stoves and the men programmed their work schedule both to build improved kitchens, and to help women build and install their stoves. In one of these villages, the youth roup volunteered to build the kitchens, as it had a continuing house construction programme and had developed appropriate skills. These cases illustrate the value of integration of rural energy programmes into other activities of rural communities and the need to involve them in decision-making.

Rural projects need to be socially efficient. Social efficiency, like energy efficiency comprises two measurements.

(a) The first is a measure of how efficiently the project promotes participation of the community to accomplish the tasks needed to be done.

(b) The second is a measure of the quality of use of human skills and institutions by the project. This latter consideration takes women's and men's roles as well as societal organization into account.

A socially efficient project would have four main properties:

(a) high responsiveness to the priority needs determined by the community;

(b) enhancement of the current roles of different members of the community;

(c) strengthening of the social organization, the cohesiveness, and the self sufficiency of the community;

(d) development of inherent skills within the community for the long term execution of a project and activities it introduces.

Table 3: Suggested Means of Measuring Social Efficiency of Rural and Household Projects

(a) Participation Efficiency

No. of People Input to Needs Assessment X People expected to benefit
No. of People Should Input to " " People expected to implement

(b) Check list for Indication of Quality of Use of People

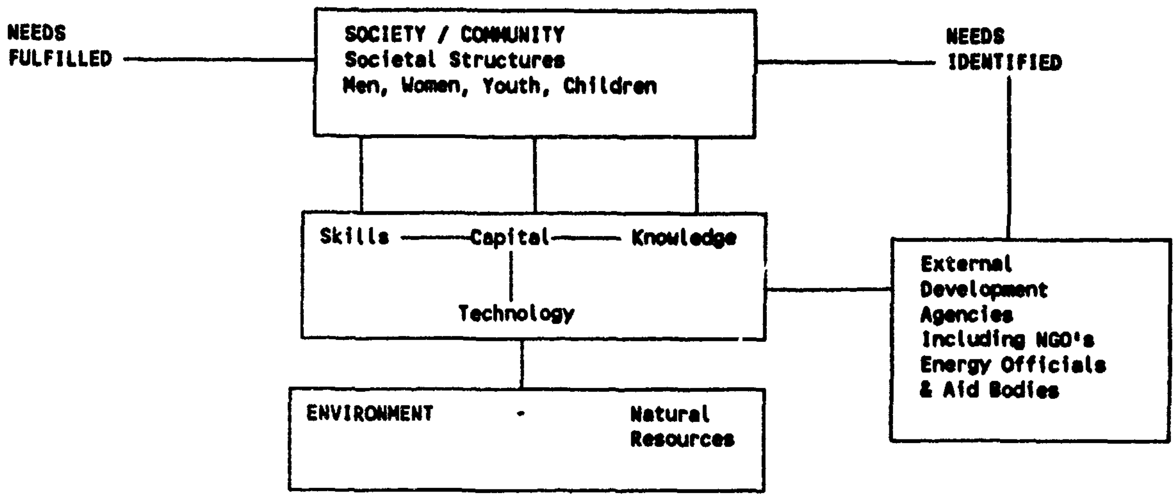
- Have consultations been made with men, women. youth?	Yes/No...3
- Are the needs priorities of each addressed by the objectives	Yes/No...3
- Will there be negative effects on women? youth? men?	Yes/No...3
- Will there be positive side-effects on any of the groups?	Yes/No...1
- Do the planned activities complement the current gender and age denominations in roles?	Yes/No...2
- Will the project establish linkages with other rural development projects that will enhance impact on vulnerable groups such as women?, children? youth?, aged?, unemployed?	Yes/No...5
- Will the project enhance social cohesiveness?	Yes/No...1
- Will the project utilize and train if necessary, local women, men, youth to deliver goods and services?	Yes/No...3
- Is the project culturally acceptable? Have social and traditional factors been taken into account in its formulation and implementation?	Yes/No...2
- Will opportunities be open for women to manage aspects of project activities?	Yes/No...2
- Does the organizational structure of the project ensure access to resources (training, land , credit, tools etc.) of women?, youth?	Yes/No...2
- Does the project's monitoring and evaluation system explicitly measure the project's effects on women and men separately?	Yes/No...1
- Does the project have a management information system that allows those managing it to monitor the effects on each group separately?	Yes/No...2
- Will the project information system utilize, result in, or enhance official collection systems with gender-segregated data (eg. Household Income and Expenditure Surveys, Agriculture Census)?	Yes/No...3
- Can the project design be modified to increase positive effects and decrease negative effects on women?	Yes/No...2

In Table 3, I have a suggested list of indicators to measure social efficiency.

The community can be a single household, a village, or a district of many villages and settlements - depending on the nature of the project. It would be useful at this stage to introduce a simple model to explain my thesis better. This is represented in Figure 3. A society or community works basically to fulfil its needs which it should identify itself - perhaps with some assistance from outside agents such as government or aid agencies. These latter agencies mainly input skills, capital, knowledge to enable the community to utilize their natural resources and their human power for the fulfillment of their needs. One could say that the fulfillment of a community's needs is like the production of the fruit by a plant.

Outside and modern day interventions through development agencies, such as energy officials or NGO development workers may be likened to fertilizers, that plants can do without, but fare much better with. One should note that too much fertilizer damages soil structure and composition and requires even more and varied fertilizer. Similarly there can also be a danger of too much outside assistance that can kill initiative in a community. A socially efficient project is like applying fertilizers at the right time and in correct amounts. Just as fertilization does not determine the shape and taste of the fruit, so community development agents should not determine the needs of the community to be fulfilled. They can assist. The determination of such needs however in a socially efficient project, belongs to the community.

Figure 3: Simple Model of Community Development



What might be the areas of concern of ordinary people, particularly of women, in the Pacific in both rural and household energy? Because rural and household energy are not exactly in the same category, as I explained before, I now wish to separate them in my discussion.

Rural Energy and Women in the Pacific

Except for Nauru and Guam, all countries of the Pacific are predominantly rural in population. Yet in most countries of the Pacific the urban/rural income gap continually widens and urbanization is an increasingly worrying phenomena. The diverse, dispersed and diffuse nature of many rural development issues, including rural energy issues make planning and management of rural programmes a difficult task. Hence busy planners tend to leave hard cases which require substantial intellectual inputs aside and concentrate mostly upon easier large scale programmes.

Amongst these difficult cases are many areas of concern to women. The depletion of coastal fish and shellfish resources for the family's daily meals, the allocation of prime land to cash crops leaving little or no land for subsistence gardens, the clearing of bush and forests for development, robbing households of convenient fuelwood sources, the growing flow of people to urban areas, leaving rural areas more sparsely populated and less and less economical to service - are all phenomena of great concern to rural women.

It is these concerns, and the solutions to them, that rural development planners and energy planners should, with the assistance of women, address. The provision of energy in rural areas would serve development better, if it were integrated into and coordinated with relevant rural programmes. Such an approach would both be socially as well as economically efficient as it utilizes peoples efforts for the production of energy within an integrated system with multiple outputs.

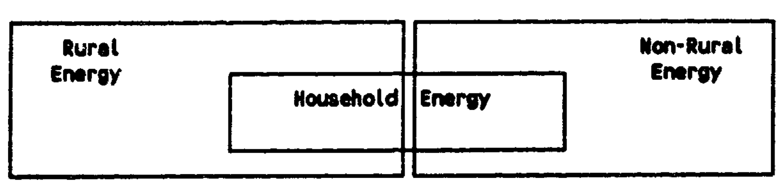
Unfortunately, energy sector plans in the region appear not to be closely associated with or integrated into rural development planning. For example, while more efficient woodstove or charcoal programmes are mentioned and fuelwood planting mooted, essential inter-departmental programme linkages of the relevant departments such as forestry, women's affairs, rural development or outer-islands affairs, public health and public works are generally weak or non-existent. The needs for crop-drying, or irrigation or local transport for agriculture are generally not considered in rural energy plans. The energy needs of the fisheries sector such as in the area of transport, fish preservation or ice production and of the communities water supply requirements should also be taken into account in the energy plans of the rural sector. I note there is often mention of rural telecommunications, of ice making, and health clinic refrigeration, but only in terms of solar PVC use.

Governments' rural energy programmes cover the gamut of needs and resources utilizable, but somehow lack the focus necessary to effectively service rural development - both economically and socially. It would appear necessary to do this through an integrated approach to the total development of rural areas -location by location, or island by island, or atoll by atoll. The island profiles currently being constructed in the Cook Is., and the UNDP integrated atoll development programme, both offer opportunities for integration of rural energy considerations. An integrated approach would favor for example co-generation systems, where burning of waste (eg. coconut husks) would both dry crops and generate electricity; or agroforestry, where intercropping with trees would result in the production of food, fuel, fibre and other biomass needs from the same plot of land. Such an approach undoubtedly requires consultation with people - both men and women, before projects and programmes are finalized. Requiring the projects/programmes to pass the tests of social efficiency as well as economic efficiency would definitely ensure people's participation and improve the chances of success.

Household Energy and Women

Household energy is a subset of both rural and non-rural energy, See Figure 4. Households, as shown in Figure 2 are usually consumers of energy, although in the case of wood, most Pacific households are both suppliers and consumers.

Figure 4: Showing the Relationship Between Rural and Household Energy



Household Energy Set Intersects Both Rural and Non-Rural Energy

It is in the area of household energy that women's concerns are paramount. They are usually the managers of households, whether these be of small families or collective dwellings such as hostels, or special homes, such as crippled children's homes. For the majority of Pacific women, household energy needs are restricted to cooking and lighting, in that order of priority. Women are largely responsible for the time-consuming back-breaking work of fuelwood collection and cooking over smoky open fires. Men do help during special occasions while children also contribute their share.

For most energy planning and policy formulation the major concern with regard to household energy is to ensure reliable supply at reasonable cost, particularly to the poorer members of our communities. Other considerations, such as energy efficiency and fuelwood depletion arise under special circumstances.

Pacific countries' energy plans do mention these concerns but lack the commitment of resources in the actual programmes that may be part of such plans. This is not surprising, as our energy planners tend to devote their entire focus upon saving foreign exchange for the country, and therefore concentrate their efforts on such issues as:

(a) petroleum pricing,

(b) developing renewable energy for electrification to replace diesel generation, and sometimes

(c) energy management measures to use commercial energy more efficiently. This is not to say that foreign exchange considerations are unimportant. But it does highlight the need for wider vision and integrated approach to energy planning in the Region.

Quite understandably, planners direct their efforts to large consumers where the impact of their policies and programmes can be significant on the national scale. It is no wonder that women's concerns, which are with household energy, largely pass un-noticed.

The majority of Pacific households cook with wood, or coconut parts and other agricultural wastes. Most of this is burnt over open fire. The majority of households still use kerosene lamps for lighting. A growing number in some countries, now supported by aid money, have solar lights. But many households in urban areas, which are serviced with electricity grids, still burn kerosene lights, as electricity costs are beyond them.

The servicing of the goal of meeting basic human needs, that many of our governments enunciate in their plan documents, requires that much greater attention be paid to household energy, the most basic need for which is for cooking. Surveys in urban areas in Fiji taken in 1981, 1982 and 1988 by both the Energy Department and the Ministry of Health show an increasing number of poor households restricting themselves to only one proper meal or even less a day. The main reasons for this are their inability to afford kerosene for cooking and scarcity of wood to burn in the urban areas.

Availability of wood is an increasing problem, both in urban and in some rural areas in many countries of the Pacific. In Vanuatu, for example, firewood supplies are getting critically short in some small outer islands. If people had the means, kerosene and gas (LPG) would of course supplement wood in such situations. Survey findings in Fiji showed increasing kerosene consumption correlating closely with increasing cash income of rural and peri-urban households. Even where fuelwood were available without the need for cash outlay, households still purchased kerosene because it was eminently more convenient to use. Obviously as a housewife's budget increases she would opt for the cleaner, easier means of cooking with kerosene or gas.

Where their budget cannot meet the costs of commercial fuels women have attempted to mount their own wood-burning stove construction programmes. This move can significantly affect national foreign exchange savings in the long term because the availability of clean efficient wood-burning stoves can stem the increasing consumption of kerosene and gas that accompanies increasing cash incomes of households.

The social and other benefits of wood burning stoves to the women and the family are of course obvious. Nevertheless, any existing projects on wood-burning technology for households have remained small and peripheral to the main thrust of all of our governments' energy programmes.

I have dwelt on cooking because it services one of the most basic of human needs - the need to be adequately fed. Lighting is perhaps of secondary importance particularly for the very poor families. The belief that rural electrification (both diesel and PVC) might increase productivity by enabling women for example to do handicrafts at night, or children to read more and do extra homework at night was shattered by a survey conducted in Fiji in 1986. Villagers interviewed overwhelmingly stated that better lighting enabled better socializing. Only where school buildings were electrified and teachers willing to supervise, were children enabled to spend more time on homework at night.

With increasing urbanization and increasing cash income, refrigeration in electrified homes is becoming more common in the Pacific. This is an important service, particularly as, for several reasons, it enables urban families to have a more varied diet and better nutrition. Greater attention now needs to be paid to the kinds of refrigerators being imported and sold for household use. More energy efficient and environmentally friendly refrigerators with lower CFCs are now available, and are often so labelled.

A small proportion of urban households in the Pacific, can and do instal domestic hot water systems. Where electric ones are used, mandatory switching to solar energy would not only help foreign exchange costs where diesel generation is the norm but would also be gentler to the household purse.

What are the Implications on Energy Policies and Programmes of Taking These Concerns of Women?

Rural Energy Policies

Women in the Pacific are probably the most potent force for rural development and the main contributors to the subsistence sector. This sector absorbs much of the "rejects" of modernization - the school dropouts and the unemployed. Taking women's concerns into account means taking rural development seriously. Further, rural development can only be achieved efficiently when women's role and contribution are fully appreciated. This is also true of rural energy development. Hence the need to ensure "social efficiency" of any rural energy projects or programmes, as explained earlier. This requires:

(a) A policy of true integration of rural energy planning with overall rural development planning.

(b) A policy of ensuring community participation and consultation in all the stages of planning of rural programmes.

(c) A policy of close consultation with all government ministries involved in rural development.

(d) A policy of strengthening skills and rural institutions to manage and maintain rural energy projects/programmes.

Household Energy Policies

In terms of household energy, taking care of women's concerns is synonymous with helping meet basic human needs for which all development agencies claim to work. Here effective energy policies would be those that:

(a) Meet household energy needs consistent with the priorities set by women and not by priorities which are driven by available technologies.

(b) Inform women and householders of the implications of energy technology choices such as for example in the choice of cookers or refrigerators.

(c) Incorporate householders behavior in meeting national goals of energy conservation rather than impose habits to meet conservation goals.

(d) Ease the burden of work upon women without jeopardizing energy supply or provision.

The implementation of these two sets of policies may require some institutional restructuring in government administrations and changes in planning procedures. Nevertheless if our countries have to achieve their development goals of equity and of meeting basic human needs, the minimum steps must be taken.

Main Ideas

1. Need to re-orient approach to rural energy planning

2. Planners priorities differ from women's priorities - reflect true needs of communities (rural and poor)

3. Success of rural energy and household energy projects dependent on "Social Efficiency" as well as "Economic Efficiency" and only to a minor extent on "Energetic Efficiency" of projects.

Most Frequently Expressed National Development Goals

1. Increasing equity - Urban/Rural
2. Greater self-reliance
3. Meeting basic human needs
4. Economic growth
5. National unity - political stability

Definitions

Rural Energy

1. A type or class of energy systems (small scale renewables)
2. Energy supply/demand in rural locations as geographically defined

Household Energy

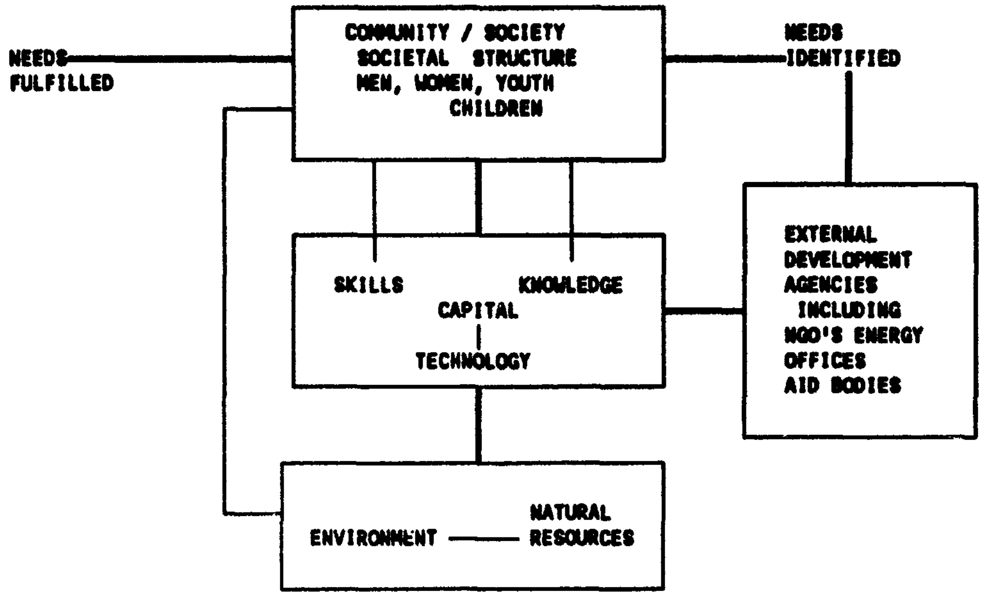
1. Energy supply and use for personal dwellings (family homes, hostels)

Relationships of Rural and Household Energy

Rural Energy | Household Energy | Non-Rural Energy

Household energy set intersects both rural and non-rural energy.

Simple Model of Community Development



Women's Priorities

Rural Development

- Depletion of natural resources
- Access to market for cash
- Social amenities/services (health, education, water, housing, etc.)
- Transport - Roads, boats
- Electrification

Household Energy

- Cooking - kitchen
  Stove
  Firewood Supply

- Processing/food preservation
  lighting

- Ironing Hot Water Etc.

Table 1: Relative Costs and Energy Expended for Different Cooking Modes in Urban Suva's HHs

Cooking Fuel	Cost/Meal/Person	MJ/Meal/Person
Wood (open fire)	up to 0.3c	7.35
Wood (stove)	up to 0.3c	6.3
Kerosene (Av. all cookers)	2.3c	2.55
LPG	29.75c	2.63
Electricity	55.05	2.41

Table 2: Relative Impacts on Energy

	People's Behavior and Priorities	Govt Policies	Technology Changes
HHE	XXX	XX	XX
RE	XXX	XX	XX
Indus.	0	X	XXX
Transp.	XX	X	XX
Comm.	X	X	XX
Agr.	XX	X	XX

XXX Important XX Sometimes Important X Rarely Important

Suggested Arrangements for Consultation with women

Decision Level		Consultation with Women
	DEVELOPMENT GOALS (Politicians)	
Energy Sector Goals		NCW Women's Office NGO Leaders Concerned Ministries
Policies/Strategies		
Programmes		NGO Women Leaders NCW Women's Office
Projects (People) - Needs Assessment - Project Formulation - Project Financing - Project Implementation - Project Monitoring/Evaluation		Village or Settlement or Urban Groups of Women.

Energy Sub-sectors

Supply Subsectors		Demand Sub-sectors
Resource	Technology	
		Household
Wood	Wood burners	Transport
Oil	Kerosene Stoves etc.	Industry
Coal	Electricity Generators	Commerce
Hydropower	Transport Vehicles	Agriculture
Wind	Lighting Equipment	
Wave		
Solar		
Ocean Temp.		

Rural and Household Energy - Efficiency Measures for Projects

Economic Efficiency .... Cost/Benefit Analysis

Energetic Efficiency .... Conservation Efficiency
.... Entropic Efficiency

Social Efficiency .... Participation Rate/Efficiency
.... Quality of Participation

WOODSTOVES PROGRAMME AND ITS IMPLICATIONS ON RURAL WOMEN AND HOUSEHOLD ENERGY STRATEGY

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Introduction

This paper aims to present some historical factors that have changed the role of Pacific women to become household cooks and energy managers and attempts to describe prevailing situation of women in the household energy related work. It will also try to describe the introduction of various improved woodstoves and present some trends seen within the stoves programme. Because woodstoves are promoted with multi-objectives, this paper recommends that stoves be used as the focal point of integrated rural household energy strategy relating to household cooking.

Historical Events and the Role of Women

Very few Pacific foods for meals require no cooking process. The cooking that was generally carried out by males and all members of the household has been exclusively taken over by Pacific women since contact with palagi 1/ households who were deemed of a superior culture.

Palagi women were seen in the kitchens and they brought with them the cooking technology of (Bombay) pots. Thus locals aspired to the Palagi way of life (the beginning of the Bombay pot syndrome) and women were relegated to be cooks, to use iron and aluminum pots and were required to cook three meals a day (when meal events were traditionally twice daily).

In the case of Fiji, the palagi authority saw it unhealthy to have the cooking area in the main house not only for the smoke produced from the grilling (which also kept mosquitoes away from occupants and insects from attacking the thatching) but also created the risk of fire. For these reasons the Fijian Native Regulation demanded that the cooking area be located outside the homes thus the birth of the traditional kitchen structure: a small obscure house located at the periphery of villages to house both the cooking area and the women cooks! The location and status of the Pacific kitchen is symbolic of the status of rural Pacific women to the present day.

The Classic Rural Kitchen

Rural kitchens vary in shapes and sizes throughout the Pacific and in some countries a kitchen does not necessarily mean a housing structure. General observable characteristics of kitchens show the following:

(a) Housing material is of inferior quality and temporary structures as compared to the homes, either totally made of traditional material or semi-traditional in structure;

1/ Polynesian term meaning of European.

(b) poorly ventilated with doors but no windows;

(c) lack proper storage area for either food or utensils;

(d) serves as a tool shed;

(e) the least maintained of all buildings in villages; and

(f) sleeping area for home pets and other domestic birds and animals.

The above characteristics indicate that the rural kitchen has very low priority in village housing. The status of rural kitchens is a risk to the health of women and children who are the main users of kitchen premises. The use of open fire cooking and the absence of proper ventilation is a serious health risk for the women and other users.

Secondly, the hygienic status of these kitchens have to be improved if we care about the health of users and the quality of meals prepared within the area. Though all health authorities have regulations for area specifications for homes, the same regulation does not necessarily apply to kitchen space per person therefore many kitchens are overcrowded under the same space specifications.

Rural Women as Household Chefs and Fuel Managers

The survival and health status of rural Pacific households rest with women as their work is directly related to the provision of basic needs for the household particularly food, water, warmth and health. One of women's major responsibilities is to ensure that there is enough fuel supply in the household for domestic cooking. With the assistance of children, women are the main gatherers of fuelwood and of its proper storage in the household.

The responsibility of women in the supply and storage of fuelwood is being threatened by deforestation and agricultural development in Pacific villages. There appears to be a definite pattern of agro-development in the villages: crops that are in vogue promoted by the government department responsible for agriculture, take up the nearest and the best land surrounding the village and sadly most of these crops are non-food cash crop controlled exclusively by the village males. There is competition for land for cash crop and fuelwood need of households. The receding edge of village forests and busharea result in women and children having to walk longer miles to gather and carry firewood back to the villages. Alternatively they either use locally perceived poor quality fuelwood or wood debris available in villages.

The Fuelwood Situation Risks the Health of Rural Women and Children

The work situation of women is worsened in the use of open fire cooking method popularly used in villages. With the inefficient combustion of the cooking method and use of poor quality fuelwood, women and children are badly affected in two ways. First, they have to spend more time and effort in gathering fuelwood, and secondly, the poor combustion of the perceived inferior fuelwood (which produces more smoke) threatens the health of the same women and children who are the main occupants forming the main traffic in kitchens during cooking time.

The Function of Improved Woodstoves for the Work and Health of Rural Women

The introduction, promotion and dissemination of improved woodstoves in Fiji and the Pacific is an integrated attempt to address women's work, the environmental conditions women work under and the fuelwood situation in turral areas.

The major objectives of the stove programme varied over the years and the emphasis placed depended on the organization involved in the promotion of stoves. The government health authorities promoted stoves (with chimneys) for health reasons only. Women NGOs emphasize stoves as an appropriate technology improving the cooking mode as well for the implied efficiency in burning of fuel wood thus lesser work for women in their fuel wood gathering work and reduces the need to clean 'black' pots after cooking over open fire. Woodstove projects also had as an objective the potential improvement in kitchen standard.

It was only in the last few years that health risk of breathing smoke from open fire have become a major emphasis with women NG0s. The use of woodstoves to create awareness of the critical fuelwood situation facing rural and urban households is receiving allot of attention from women NGOs.

Increasing concern with the rate of bush clearing and deforestation in the Pacific is a real threat to the fuelwood supply for rural households. The promotion of improved and efficient stoves is seen as a means of conserving available fuelwood. We know however that no woman cuts down a tree for firewood: she does not have the energy for the work (nor is she destructive to nature and she cannot carry away all the trunks and branches). The worsening fuelwood situation is attributed to agro-industrial and economic expansion programmes rather than from fuelwood gatherers themselves. Therefore, stoves will not save trees in the Pacific islands.

Increasing concerns on the increasing fuel import costs have prompted Pacific governments to adopt policies to promote efficient use of available fuelwood, support woodstoves programmes and look at alternative sources of energy.

Fuelwood is Here to Stay

Rural households continue to use fuelwood for a number of reasons: because of its free availability; cooking for large families; and traditional functions will become too expensive if a new energy source is used. The capital required and running involved in switching to another fuel is beyond the income of the majority. Alternative fuel will mean the loss of some traditional knowledge and skills that require some processing with the use of open fire e.g. fish smoking, tapa making and smoking and boiling pandanus needed for mats to mention a few.

Trends in the Promotion and Dissemination of Woodstoves

Though various models of improved woodstoves have been promoted nationally and regionally, the coverage of the programme or the actual adoption of the technology is very low with a heavy bias towards urban and peri-urban dwellers because affordability is a major factor in the adoption of the technology. The methodology for promotion and dissemination tend to be very piecemeal and many NG0s have altogether abandoned the cause of woodstoves projects. Governments that have policies on the promotion of improved woodstoves are at times not forthcoming with support for NG0s, especially women NG0s, in their actual dissemination activities.

The woodstove programme has had a distinct pattern: many promoters pointing to the technology and praising its advantages over openfire but very few disseminators. Numerous training workshops have ensured that at least a village stove technician is available in each district in Fiji, but the actual adoption of the technology in the rural districts does not indicate that such personnel with special skills exist in the area.

The sexual division of labor amongst woodstoves workers is another common feature. The introduction and promotion of improved woodstoves into Fiji and the Pacific was first introduced by women NGOs to address specific issues of concern to women and the promotion exclusively done by women. However technical training by higher institutions for woodstove construction has been exclusively limited to males who tend to be employed to do the technical part of woodstove activities (as the case in Fiji). More women continue to be stove promoters and makers on voluntary basis as compared to the number of women who do the work as part of their paid job. All government and quasi-government bodies involved with woodstoves have continued to employ all male teams as in the case of Fiji (even this conference appear to be heavily male biased, judging from the names on the tentative list of speakers and participants). The pattern indicates that Pacific males control the promotion of woodstoves in terms of making policies, research and development, training and control of funding. The actual dissemination of woodstoves remains to be carried by women, the majority of whom do it on a voluntary basis, to women.

The Promotion and Dissemination of Improved Woodstoves as an Integrated Rural Energy Strategy

There are many reasons that support the promotion of improved woodstoves in the Pacific that can be used as the pivotal point of any proposed integrated rural energy strategy addressing cooking fuel.

Woodstoves have been promoted for a multitude of objectives but sadly enough exclusively promoted by women' to women. The woodstove as an appropriate rural technology can be easily acceptable by potential users. Rural communities want to see tangible projects that will be of daily use.

For the above reasons an integrated rural energy strategy can be developed to be supported with relevant vernacular reading material addressing the following rural issues which have been raised in this paper:

(a) The status of rural women;

(b) Women and health;

(c) Rural kitchen environment;

(d) Workload of rural women;

(e) Fuelwood supply and situation;

(f) National fuel situation;

(g) deforestation and tree planting;

(h) community fuelwood lots; and

(i) appropriate technology for rural users

The above mentioned are some issues that can revolve around any improved stove program if we care about the health of women and children as well as about energy situations in rural areas especially that which directly relates to meeting the basic food needs of rural households in the Pacific.

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WOMEN AND THE MANAGEMENT OF ENERGY RESOURCES

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Introduction

This paper describes the evolution of ESMAP's women and energy strategy, reports on progress in implementing its women and development strategy, and highlights some important WID issues for household and rural energy.

ESMAP undertook the elaboration of a women and energy policy framework and companion action program beginning in 1988, as part of a World Bank-wide initiative to enhance the role of women in development. The work progressed in three phases: Phase I reviewed the "state-of-the-art" of women and energy of various agencies and organizations, including NGO's. This stocktaking exercise was designed to bring to ESMAP an understanding of the accumulated research and experience of those already working on different dimensions of women and energy. It also aimed to identify gaps and priority issues for ESMAP to consider in the formulation of its strategy. The findings of Phase I are summarized in "Women and Energy The International Network: Policies and Experience A Resource Guide".

Phase II then examined ESMAP, its activities, reports, stated priorities and experience with a view to assessing the nature and degree to which women have been involved in our work program to date. This phase was marked by in-depth discussions with ESMAP and UNDP staff, as well as World Bank regional staff who have worked with ESMAP on energy issues. Based on the work of Phase II, Phase III set out a women and energy strategy and action plan to more effectively involve women in the management of energy resources. To implement this program, ESMAP has conducted an international recruitment to identify a Women and Energy Coordinator. Ms. Maurizia Tovo, an Italian national, has recently joined the Program. Her responsibility will be to evaluate the impact of the women and energy measures taken to date, which are described below, and to design a comprehensive program that will be submitted to ESMAP's donors for financing.

Designing a Strategic Framework

From the beginning, the ESMAP program has recognized the centrality of women in its demand management activities and has incorporated their views, preferences and needs as energy consumers, mostly in the improved stoves programs. Examples of these earlier, free-standing cookstoves projects sponsored by ESMAP include: the Burundi Improved Charcoal Cookstove Strategy (1985); the Ethiopia Cooking Efficiency Project (1987); and the Niger Improved Stoves Project (1987). All of these activities relied heavily on an assessment of the needs and preferences of women for cooking fuels and equipment to design suitable stove models for mass marketing. Cookstove demonstrations as well as household use were the main instruments used to adapt stove models to actual home use conditions. These activities have also included follow-up surveys to determine the suitability and reliability of the cooking equipment over a longer period of time.

More recent ESMAP improved stoves projects continue to anchor energy savings through improved woodfuels stoves in an in-depth evaluation of user preferences. Examples of these free-standing stove activities include the Ghana Improved Charcoal Stoves Project and the Rwanda Charcoal Stoves. The enhanced understanding of consumer desires has led to improvements and adjustments to the stoves as well as to the re-design of marketing campaigns that earlier promoted energy savings as the prime selling feature. Today, these campaigns associate the improved cooking equipment with less smoke, shorter cooking times and improved lifestyles, all of which have been identified as important to the women who use them.

As the work on women and energy progressed and, indeed, as ESMAP has continued to learn by doing, it has become clear that ESMAP could undertake a stronger and more focussed effort to pay more explicit attention to women's issues as they affect the management of household energy. Women are, after all, key actors in the household sector throughout the developing world. They are, almost without exception, the primary collectors of fuelwood. When fuelwood is commercially marketed, as is the case for the urban energy market, it is typically the men who produce it, sell it and haul it the frequently long distances to the urban market. There are, nonetheless, exceptions even to this rule: in one region near the capital of Mali, in West Africa, women harvest the fuelwood, sometimes even hire men to do it, and group together to haul the wood on trucks or, in some instances, even to rent railroad cars for woodfuel transport.

Women are also the prime users of fuelwood in both the rural and urban sectors, using it in their households, in their agricultural activities, and in a vast array of income-generating informal and small-scale sector endeavors. In the cities, women are heavily represented in the informal sector in biomass-intensive activities ranging from roadside restaurants and beer-making, to soap production and fabric dyeing. Women's reliance on biomass fuels goes, of course, much further. In many regions throughout the development world in fuelwood-producing villages close to urban centers, women engage in similar informal sector productive activities, frequently locating themselves along the main road links to the city center, where they sell their products to woodfuel haulers and others on their way to town.

The importance of women to the management of natural resources does not stop there. Women have vital knowledge about the use and management of trees and other forest plants; they contribute their labor to forest industries and derive much needed income for their families from plant fibers, medicinal plants and herbs, etc. As managers of forest resources, agricultural laborers, and as prime users of woodfuels, women are, therefore, keenly aware of the need to protect and conserve trees and forests. This pivotal role in the natural environment adds to their already heavy responsibilities, as deforestation and associated environmental damage accelerate, since it is they who are responsible for meeting their families' basic needs and for household fuel security.

Women are, therefore, central to decisions on questions of energy at the household level both for consumption, as well as that of the informal sector, and production-related activities. Yet, because they have less access to land, services, education, extension marketing technology and credit, they frequently cannot derive the full range of benefits from energy programs. This is especially so for women in the rural sector, where cultural and social inhibitions constitute formidable obstacles to improving their productive opportunities and family welfare. Although it is hazardous to generalize, many of these social and cultural barriers have begun to relax in the urban context, where there are numerous examples of women taking leading roles in productive endeavors and where, as a result, they can more fully benefit from energy efficiency and conservation programs. Nonetheless, project interventions in urban energy must also pay special attention to identifying women's roles and opportunites to ensure their more effective involvement.

That women participate across the spectrum of energy demand and supply is but one aspect of a very complex problem. These rural and urban women are both young and old; head their own households or are members of a multi-family unit; manage their own financial resources or rely on their husbands for all or a part of their funds; live in societies that severely constrain their opportunities for social and economic advancement or live in others that invite them to take fuller advantage of their economic potential. Many women will never be candidates for improved stoves programs, because of income constraints, but could generate substantial energy savings through the introduction of programs that stress energy management within traditional cooking practices.

On the forestry management side, women enjoy rights to tree and land tenure that vary greatly from society to society and those rights--or absence thereof--can constitute a prominent feature in successful strategies to manage commercial fuelwood schemes. For example, a forestry management scheme for an Eastern African capital city interdicted fuelwood harvesting for the urban market, provided severe penalties for those caught and also compensated evicted households with land rights elsewhere. Some 20,000 women fuelwood carriers whose families depend entirely on wood sales from these forests, but who had no rights at all to these forest resources, were overlooked in the project analysis and have greatly suffered as a result. Accurately assessing the role of gender should not be confounded by the diversity and complexity of such situations. Rather, it requires that the issue be evaluated within its site-specific context and considered as an essential element of the overall natural resource management framework.

ESMAP's Women and Energy Framework

This brief sketch of women's involvement in energy management is presented to underscore the complexity of the gender issue as well as the need for more reliable information. Successful household energy programs to meet rural energy needs, satisfy the spiraling demand for energy from the urban sector and, at the same time, preserve and protect the natural resource endowment requires that ESMAP learn much more about women's participation and the obstacles and constraints to fully tapping their productivity and improving their welfare. The women and energy strategy work has helped to identify the strengths and weaknesses of our present approach and has made a good case for new initiatives in this arena. ESMAP is committed to launching a broad-based effort to assess and strengthen the roles of women in the design, implementation and monitoring of its activities. Recognizing the critical need to be flexible and to be prepared to make mid-term adjustments as required, the Program, as set out below, is being carried out in three phases:

(a) short-term actions that ESMAP can introduce at zero or little additional cost. The objective is to shift and refine staff work approaches/methods and adapt work tools to better incorporate gender concerns. Examples of short-term measures include the more extensive use of sociologists from the start of a project activity; inclusion in terms of reference of tasks related to the integration of gender concerns into the specific activity in question; definition of reporting and monitoring mechanisms for the women and energy strategy; and appointment of a steering committee within ESMAP to monitor progress;

(b) medium-term actions: A limited number of prospective ESMAP activities has been identified for testing and refining the more intensive gender emphasis. It is intended that, at the completion of these activities, attention would be paid to the lessons learned and the impact of those lessons on subsequent project work. This period will also be marked by more intensive networking by ESMAP within the international women and development network; increased cooperation with the donors, the UNDP and other international agencies/institutions concerning women and energy programs and activities and; centered around women and energy issues; and

(c) longer-term actions: An applied research program in areas of special interest to women and energy would be pursued. Topics under consideration include: dietary changes and the fuel transition; alleviating urban poverty: cooking and lighting infrastructure standards; and the informal sector and energy use.

Progress to Date

Progress in more explicitly integrating attention to women and energy concerns has been somewhat delayed by unforseen obstacles in recruiting the Women and Energy Coordinator. Nonetheles, with Ms. Tovo on board and fully operational, the design of a more comprehensive and detailed plan is well underway.

While awaiting the Coordinator, ESMAP has taken several steps to reinforce its understanding of women's involvement in the delivery and use of household energy as well as in the protection of forest resources. In household energy strategy activities in Sub-Saharan Africa and in the Caribbean, an internationally recruited female sociologist was hired to participate, together with the energy economist, in the design of the survey instruments. In the West African case, the sociologist had inputs into the design of the questionnaire. Based on this experience, the sociologist was made fully responsible for the design of the questionnaire in the Caribbean case as well as for the identification, training and supervision of the enumerators. One of the lessons drawn from the West African case was the need to ensure that both international and local sociologists have a clear understanding of the objectives of the household energy strategy and the expected outputs. This was achieved through thorough briefings early in the study execution.

One of the fundamental reasons for this change in the survey design methodology was the increased value attached to qualitative information on women's responses to cooking equipment and alternative fuels. This information was also deemed vital for identifying potential clients for these alternative fuels and the designing of appropriate marketing mechanisms. This earlier and more comprehensive participation by an expatriate sociologist, together with the national sociologists, permitted a broader profile to be drawn of inter-alia, the needs and preferences of women consumers, constraints to fuelwood substitution, their energy priorities both for consumption and production and, indeed, their priorities for basic services for their families.

The more comprehensive understanding that can be drawn from an expanded and disaggregated data base has, on the one hand, raised the awareness of those working on the activities and, on the other, permitted the tailoring of strategic recommendations to increase the access of women to improved energy services through credit, improved information, training etc. It is important to emphasize that the intention is not to design free-standing WID components, but rather to ensure that the household energy strategy and policy recommendations that emerge from the analysis of the data will have a greater chance for success because of the enhanced understanding of all of the involved actors.

While, in general, household energy strategy studies and improved stoves projects have used women enumerators to carry out the surveys in its demand management work, ESMAP has attempted to re-enforce their active participation in these studies on the demand as well as on the supply side. For example, consumer advisory panels drawn from representative socio-economic strata, were established at the start-up of a household energy strategy study in one West African country. These neighborhood panels, some of which were made up exclusively of men, others of women, and one panel mixed, were organized both to facilitate access to the local population as well as to provide feedback on the findings of the various sub-components of the activity and the suitability of the final strategy. While this initiative was appreciated by the local population and probably enhanced access to the local population, its value as a sociological tool must await broader application.

Another vehicle for heightening awareness of the roles--and problems--of women and energy in the West African household energy strategy was the pairing of local sociologists with the other national technical experts working on different aspects of the strategy. The exchanges of views and perspectives that resulted from this experiment provided, according to the foresters working on the supply side, a keener understanding of women's participation and of the potential for their increased involvement. The organization of team meetings during the conduct of the study to discuss the women and energy issue, together with other relevant issues associated with the surveys, served to re-enforce these understandings, especially amongst national staff.

More detailed analysis of biomass-intensive informal sector productive activities can be expected to open up avenues to encourage and strengthen women's productive opportunities while, not incidently, providing a more detailed perspective on urban energy consumption patterns and trends. Rapid urban growth, fueled by rural-urban migration, provides a flourishing environment for an expanding informal sector that absorbs the bulk of the urban poor who do not qualify for or who cannot find jobs in the formal sector. It is often difficult to distinguish the informal sector from the household sector, where as much as 70% of household heads can be active in the informal sector. What is clear is that the informal sector is frequently the only source of employment for women who, lacking skills and training, must seek work in these low-paying jobs.

Data suggest that woodfuel consumption by the informal sector can represent anywhere from 10-20% of total urban fuelwood use. These activities range from roadside restaurants, fabric dyeing and brickmaking to bakeries, beer brewing and soapmaking. Although difficult to quantify, informal sector activities constitute a large proportion of urban economic activity, and can be as high as 90% of the total number of manufacturing and service sector establishments. Women operating in and owning such establishments could benefit from energy conservation and fuel substitution programs. Because of the increased economic incentives to conserve energy in the informal sector, it could also be expected that women participating in such programs would be more willing to use similar energy saving practices in their households than is frequently the case.

For these reasons, ESMAP has begun to look at the informal sector more systematically in its household energy work. One of the main research areas of the Women and Energy Coordinator will be the women and the informal sector, the results of which could be expected to re-enforce our understanding of how best to translate this information into strategic recommendations.

A more recent innovation in ESMAP's household energy work with implications for women is the hiring of a consultant to examine the role of household energy in the national accounts. This work, which is also being carried out in Sub-Saharan Africa, will assess the problems associated with capturing the value of household and traditional energy in national accounting methods. One of the critical issues that will be explored is the underestimation of the value of household labor for collecting traditional fuels, which is of direct relevance to women since it is they who are the principal fuelwood gatherers.

Future ESMAP work will need to intensify efforts to collect data on women's roles on the management of fuelwood resources for the urban markets. Women have traditionally played fundamental roles in both the production and use of trees within the rural context. However, because it is typically the men who are involved with tree management for commercial purposes and, in particular, the harvesting and transport of woodfuels to the urban centers, women and their relationship with this natural resource environment is frequently overlooked. Nonetheless, these women frequently make use of these same forests and trees for their own subsistence and productive rural activities. Strategies and projects that rationalize fuelwood markets without properly accounting for women's access and use of these same wood resources could result in substantial costs for the women concerned and their attendant effects on family welfare.

This feature of fuelwood markets will require research into women's tree tenure and the extent to which these rights can be used effectively to foster more sustainable fuelwood production systems. Tree and land tenure arrangements vary widely across the developing world as do the rights and privileges of women in this regard. Nonetheless, an in-depth understanding of the site-specific land and tree tenure arrangements can be critical to creating the right incentive environment to both plant trees as well as to manage those that exist.

ESMAP's efforts to strengthen this aspect of its program will continue and will be reassessed in light of our experience, and, most critically, feedback from the involved countries. ESMAP has no first hand knowledge of the roles of women in household and rural energy in the Pacific Island countries. It will be of considerable interest, therefore, to learn the extent to which ESMAP's experience to date, both in reflecting on how to address the women and energy issue as well as in the results from household energy work in other countries, is applicable in the Pacific Island context. Feedback from Pacific Island representatives during the course of the seminar will be therefore, both welcome and helpful to ESMAP in refining its approach to these issues and increasing its understanding.

XI. RECOMMENDATIONS OF THE WORKING GROUPS

OVERVIEW ON HOUSEHOLD AND RURAL SECTOR WITHIN PACIFIC ISLAND COUNTRIES

Introduction

The objective of this brief overview paper is to identify and prioritize the key issues which relate directly to the provision of competent management and the continuing development of the household and rural sector within Pacific Island countries. Necessary linkages with other sectors and organizations are also identified.

Planning and Management

Determination of policies and priorities: It is recognized that national governments presently place a low priority on energy sector development and that a number of Pacific Island countries do not have clearly defined policies with respect to a number of energy sector planning issues including the household and rural sectors. There is a recognized need to establish clear, sound and coherent policies related to energy sector development, that the development of these policies is fundamental to the overall development process and that they should be developed within the overall national policy framework.

There are presently significant difficulties in establishing and prioritizing national energy sector development objectives. In some cases, energy departments are not governed by appropriate legislation defining their role or status within the overall national development process. Energy policy initiatives are sometimes overridden by existing legislation governing aspects of the sector (power authorities, fuel pricing).

In most Pacific Island countries, there is a growing demand for limited technical skills in economics and engineering with priorities within national governments tending to favor other sectors. There is a need for energy departments to institute and develop career opportunities for their staff in order to retain and develop local know,ledge and experience.

Energy planning offices face difficulties in clearly defining their role within the government bureaucracy and within national development framework. Work programmes are often developed from the bottom up with little di.ection coming from senior administrators or politicians. The ability to implement change is often dependent on relationships developed with key decision makers rather than through established review procedures.

Data Needs

Data base development: In order to determine priorities within the sector, a national energy data base must be developed to provide appropriate information relevant to the sector. Energy supply and demand data and energy use patterns need to be determined in order to assess both existing and likely future energy requirements, both at a national and household level. Energy end-use surveys are one method of providing this information and will assist in defining appropriate responses to consumer needs.

Resource assessment: Long term monitoring programmes are necessary to determine the overall national energy resource base. Long term monitoring programmes therefore need to be established or extended.

Technology Determination

In many Pacific Island countries, supply of energy to the rural sector utilizing renewable energy resources offers the only viable and potentially self-sustaining approach in the short to medium term. Appropriate technologies utilizing these resources, therefore, need to be determined along with the development of local expertise and management infrastructure. Electrification technologies which appear to offer potential for implementation within rural areas of Pacific Island countries include biomass photovoltaics and small hydro.

Relationship to Other Sectors

It is recognized that the projects implemented with the aim of satisfying a perceived need within the energy sector do not always reflect and satisfy the needs of the people for whom they are designed. There is therefore a need to be aware of activities and priorities in other sectors through regular dialogue with other government departments and community/womens groups. These need to be established and maintained in order to successfully develop appropriate mechanisms and to implement projects through which overall national energy policy objectives can be achieved.

In recognizing the limited capabilities of the energy departments, closer cooperation with the private sector is also warranted in providing the means necessary to implement policy initiatives.

Relationship With Funding Organizations

A closer working relationship with financing and donor organizations needs to be established in order to ensure an understanding of national priorities and goals is developed and maintained. It is recognized that, in many cases, energy sector development initiatives are donor driven through, for example, the offer of finance for specific projects, conditions placed on finance for particular projects etc. However, it is also recognized that funding agencies can play an important role in the implementation of policy initiatives through these apparently restrictive measures.

Energy/Environment Interaction

There is a need to identify and prioritize key energy/environmental interactions in order to protect the national resource base of Pacific Island countries. To date, little work has been carried out in this area within national governments.

Energy Needs of Households and Rural Areas

Households	Rural areas
Cooking	Crop and food drying/processing LightingTransport
Refrigeration	Communications
Water heating	Agriculture/fisheries
Air conditioning?	Sawmilling/woodworking
	Mechanical tools
	Govt/community services

It is hard to distinguish between basic needs and "luxuries" - these vary with income and expectations.

Recommendations:

Energy use surveys should include surveys of user priorities. Donor agencies should take user priorities into account in project evaluation.

Data Needs

The aim of data collection should be to assist authorities to develop and apply policies and programs. The working group identified the following data requirements for general surveys of rural and household energy supply and demand.

- Assess rural development needs and energy priorities (maybe in cooperation with other government departments)
- Statistics on current fuel consumption levels and end use patterns
- Prices and availabilities of commercial fuels, availabilities of non-commercial fuels
- Rough estimates of local energy resources (solar, biomass, wind, hydro)
- Household cash incomes, or indicator variables such as housing standards. Remittances should be treated separately as they can be very irregular.
- Information on social issues (men's/women's responsibilities, decision-making processes).

Data requirements will differ for special purpose surveys such as:

- Kitchen/cooking needs (maybe best done by ministries of rural development/womens' affairs)
- Pre- and post-electrification surveys

- Biomass supply/demand surveys (on request in problem areas - involve agriculture/forestry)

- Energy resource surveys (location- and need-specific)

- Energy conservation surveys (eg. concentrate on electrified households and government buildings)

- Energy demand for rural development centers (industries and or government services). Energy requirements and technology choice should be taken into account from project inception and not as an afterthought. Requires coordination between energy office and other govt. departments.

Methodology for Energy use Surveys

- Sampling: factors such as geographic location, population distribution, location of rural industry and government services, and economic groupings within villages should be taken into account when determining sampling patterns.

- Training of surveyors is important: Questionnaires will usually be in English, but surveyors must be able to ask questions in local language and translate answers back to English. (Questionnaires must be pretested).

- Protocol (obtaining permission to survey, explaining purpose of survey) and cultural sensitivity (not asking offensive questions) are important. Local people can assist and provide valuable interpretation of results but generally should not actually conduct surveys.

- Use appropriate, familiar measurement units (e.g. bottles rather than liters, for kerosene)

- Ask questions of appropriate people (e.g. questions on stoves and kitchens to cooks)

- Only measure wood fuel consumption if supply problems are evident. Forestry and agriculture staff should be involved in wood fuel issues.

Recommendation: A follow-up visit (to rural areas) or radio/press publicity (urban areas) to give a summary of the survey results to the people surveyed should be an integral part of future surveys.

Interdepartmental Coordination

This was seen as a key problem in several countries. Energy offices found it hard to obtain relevant data from other departments. PIC statistical offices could collect some relevant data in the course of general statistical surveys and censuses. Exchange and study of forestry, rural affairs, women's affairs) should be routine. Building up personal contact with key people in other departments is essential.

Survey Design and Processing

Recommendation: PIC governments (energy offices and statistical offices) should be provided with microcomputers capable of analyzing survey data. Appropriate training is required for PIC government staff in survey design and analysis so they are not dependent on consultants' reports, and can design and implement their own surveys. Training may include in-country training from consultants, and visits from or to other PIC workers experienced in surveying.

Interpretation of Survey Results

Recommendations: PIC energy staff should be trained in interpretation of survey results, and use of results in formulation of energy policy and programs. Training is also needed in how to present survey results to decision makers. In some countries, because of rapid staff turnover, the current energy office staff are unaware of surveys that have been carried out. Forum Secretariat/pedp energy staff should provide to each member country a list of all energy-related surveys known to have been carried out in that country.

Biomass or fuelwood remains the main fuel for most rural and poor urban households, in the Pacific islands. Most cooking is done with fuelwood, usually over open fires, with the balance mainly using kerosene. However, fuelwood and biomass resources are being rapidly depleted, or, because of maldistribution, are increasingly inaccessible to some populations, particularly those in urban and peri-urban areas. Coupled with increasing scarcity of fuelwood is the dramatically escalating price of kerosene and other fossil fuels, which make the fuel transition from fuelwood to kerosene or other biomass substitutes like LPG and electricity, problematic. Furthermore, problems related to the current abundance of fuelwood in many areas, land tenure problems related to communal tenure and control over public urban lands, the absence of enforceable legislation protecting fuelwood resources, and subsidies to fuelwood substitutes, which often lead to an underestimation of the current and long-term importance of biomass resources as perhaps the only viable energy alternative for low-income households, are all complicating factors.

Although the exact issues, priorities and strategies vary from country to country and within countries (because of the great natural, economic, political and cultural diversity in the region), the main issues, priorities, strategies and recommendations seem to include the following:

Major Issues and Priorities

Major Philosophical Issue

Given the uncertainty and increasing costs of fossil fuels (both at the household and national levels, in terms of foreign exchange) and the cost and technical and management problems related to other biomass substitutes, the question must be asked as to whether the transition from biomass to other energy sources should even be encouraged.

Resource-based Issues

1. High, and in some cases increasing, reliance on biomass fuels by household and boarding institutions.

2. High rates of deforestation and agrodeforestation, particularly due to agricultural and residential landuse and scavenging for fuelwood in urban and peri-urban areas.

3. Maldistribution of fuelwood resources and high cost of transport.

4. Poor knowledge of quantity, quality and distribution of fuelwood resources, in particular, knowledge of existing agroforestry based fuelwood systems of the Pacific islands.

5. Increasing time and effort required to acquire fuelwood.

6. Decreasing availability of high quality fuelwoods.

7. Underutilization, in some areas, of available biomass resources.

8. Underutilization of domestic and commercial biomass waste.

9. Failure of fuelwood users to replant fuelwood species.

10. The long-tern sustainability of biomass based energy systems.

11. Fuelwood collection-induced deforestation impacts on the environment which in turn affects agricultural and fisheries production, wildlife resources, water quality and other development activities.

Economic Issues

1. Low household incomes and cash availability to purchase fuelwood and/or biomass substitutes.

2. Lack of financial resources to use biomass substitutes for cooking.

3. Increasing cost of fuelwood in urban and peri-urban areas.

4. Rapidly increasing prices of kerosene and biomass substitutes.

5. Increasing balance of payments problems and use of foreign exchange due to increasing dependence on imported non-renewable resources not available in the region.

6. Current subsidies of biomass substitutes leading to an undervaluation of the biomass resource and biomass substitutes.

7. Failure of alternative energy developments to reverse the process of deforestation, which is basically a result of economic pressures on the people involved.

Technology-based Issues

1. Inefficient use of biomass fuel due to predominance of cooking over an open fire.

2. Poor understanding by policy makers and energy planners of existing agroforestry and fuelwood production and acquisition strategies.

3. Failure of fuelwood plantation development in the region.

4. Increasing health risks, particularly to women, related to increasing use of poorer fuelwood species.

5. Inappropriate woodstove technology development.

6. Poor acceptance rate, ineffectiveness and maintenance of improved woodstoves.

7. Cultural acceptability of, and cost and amount of fuelwood needed to produce, charcoal.

8. Low rate of rural and peri-urban electrification.

9. The limited range of economically-viable options for providing alternatives to biomass and fossil fuels for cooking in isolated and highly-fragmented island communities.

10. Relation between fuelwood scarcity, increasing kerosene costs and the increasing consumption of nutritionally-inferior processed foods and the increasing incidence of nutrition-related disorders.

Policy-based Issues

1. Lack of attention to biomass resource maintenance and development in the context of national development.

2. The need for biomass resource assessment.

3. Inappropriate agricultural development strategies which lead to deforestation, agrodeforestation, and the destruction or undermining of fuelwood resources and production strategies.

4. The need for enforceable legislation to control deforestation, agrodeforestation and the scavenging of urban fuelwood resources (the need to address the "tragedy of the commons" in relation to public and communal fuelwood resources).

5. Lack of systematic government and international aid community support to fuelwood systems and improved wood stove development.

6. Bias of local and international energy development policy to commercial energy development and conservation and electrification.

7. Lack of community awareness and the need for emphasis in formal and non-formal education and the media on the importance of fuelwood resources and their maintenance to sustainable development.

8. The need to improve the utilization of domestic and commercial biomass waste.

9. The extent to which government subsidization of biomass substitutes e.g., electricity, kerosene, LPG) should be continued and whether such subsidization can lead to sustainable energy development or whether it only serves to undervalue both biomass and biomass substitutes.

Culture-based Issues

1. Ineffectiveness of government conservation and land use policy and legislation due to communal tenure to land-based resources (e.g., inland and mangrove forest resources)

2. Taste preference for fuelwood, in particular favored species of fuelwood, for cooking owing to taste of food, speed of cooking, level of heat for various purposes).

3. Widespread importance and fuelwood demands of the weekend earthen oven or barbecue meal.

4. Western-biased rural and urban development projects and economic and environmental assessment which pays little attention to the impacts of development on fuelwood systems and other elements of the subsistence economy.

Practical Strategies to Address the Biomass and Fuel Transition Problem

1. Protection or promotion of existing fuelwood species and systems within the context of rural and urban development project/strategy design within all relevant sectors.

2. Enactment and enforcement of legislation protecting fuelwood resources.

3. Promotion or introduction of appropriate fast-growing fuelwood species or fuelwood agroforestry systems.

4. Establishment of fuelwood plantations or reserves.

5. Improved domestic and commercial biomass waste utilization.

6. Efficient woodstove development, distribution and promotion.

7. Subsidization of biomass substitutes to take pressure off current fuelwood resources.

8. Use of solar water heating to replace fuelwood use for this purpose.

9. Rural electrification for cooking.

Conclusions and Recommendations

Given the pressing fuelwood and kerosene energy needs of Pacific communities, and the importance of the Pacific Regional Energy Assessment Programme, the following conclusions could recommendations should be considered.

Conclusions

1. Fuelwood and biomass will remain the most important energy resource for most low-income families in the future.

2. That increasing fuelwood demands on diminishing resources will lead to increasing deforestation and associated environmental, economic and cultural deterioration/underdevelopment.

3. That current agricultural overemphasis on the monocultural expansion of export cropping will lead to further agrodeforestation and the destruction of existing sustainable agroforestry-based fuelwood production strategies.

4. That legislation or environmental impact assessment procedures protecting fuelwood resources are either non-existent or not currently enforced, often due to nature of land tenure systems.

5. That current inefficiency of biomass use (e.g., cooking over open fires) puts undue pressure on a limited resource.

6. That kerosene and fossil fuel alternatives to biomass will become increasingly expensive and beyond the means of most low-income households.

7. That the biomass-fuelwood transition to alternative fuels is becoming increasingly problematic.

8. That there is considerable scope for the protection of current fuelwood resources and Sustainable agroforestry-based fuelwood systems, if policies to do so are implemented immediately.

9. That there is some scope for the establishment of fuelwood plantations or woodlots in rural areas, peri-urban areas and by boarding institutions with sufficient land.

10. That there is considerable scope for increased use of household and commercial biomass waste e.g., offcuts from timber operations.

11. That part of the responsibility for the biomass/fuelwood energy crisis of poor can be attributed to the overemphasis by governments and aid-funding institutions on commercial energy, primarily fossil-fuel related development, and the associated neglect of subsistence production and incomes, including fuelwood, as a basis for the wellbeing and development of low-income partly monetized communities.

12. That some appropriate alternative to biomass fuels, such as solar water heating can be viable means of taking pressure off fuelwood resources.

General Overall Conclusion: That for most people, in particular the increasing numbers of low-income people, the transition from biomass and fuelwood to alternative energy sources will be problematic, not economically feasible, or not even advisable. If something is not done in the near future, many pacific island households and communities will be tightly locked into the vicious circle of fuelwood scarcity, environmental degradation, declining agricultural productivity, malnutrition and poverty.

Recommendations

Based on the above issues and priorities, success or failure of corrective policies or strategies to address the biomass fuelwood transition problems, and conclusions, the following recommendation are presented:

1. That surveys of fuelwood resources and fuelwood production and acquisition systems in rural and urban areas be seen as a priority as a basis for assessing potential strategies for sustainable biomass development programmes.

2. That enforceable legislation be enacted to protect existing fuelwood resources, particularly resources, such as mangroves, coastal forests and inland forest of strategic ecological, economic and cultural importance.

3. That governments and aid-funding agencies require that the protection of fuelwood resources be an integral consideration in all agricultural, forestry and agroforestry development projects, so as to minimize deforestation and agrodeforestation.

4. That multipurpose fuelwood species be tested, selected, multiplied and systematically distributed for planting in rural and urban areas.

5. That fuelwood plantations/woodlots be established in appropriate areas and by appropriate institutions e.g. , boarding schools, prisons, etc.).

6. That agroforestry-based fuelwood development be based on the improvement of existing systems, through the introduction of appropriate new species or systems, rather than on the wholesale introduction of systems from outside the Pacific.

7. That the planting of living fencing using prunable/pollardable/coppiceable fuelwood species, be systematically promoted in rural and urban areas.

8. That the improvement, distribution, promotion and technical training needed to ensure the production and maintenance of efficient woodburning stoves be made a priority.

9. That the energy crisis and the importance of fuelwood and kerosene to the quality of life in low-income households be made the FOCUB of systematic non-formal education programmes and that units be written as resource materials for examinable subjects in the formal school curricula.

10. That solar water heating and the use of fuelwood substitutes be subsidized in an attempt to take pressure off existing fuelwood resources.

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General Summary and Policy Statements and Strategies

Almost all Pacific peoples use firewood/biomass as their primary cooking fuel. For the vast majority, biomass is perceived as a free good and will remain so in the Pacific Islands for the foreseeable future. Some small pockets of urban/peri-urban fuel shortages are developing but this is generally in a sea of plenty. Urban populations convenience switch with prices dictated, inevitably, by world market prices and these should not be interfered with.

Cooking is a social necessity in the provision of a basic need, food. The perception of wood as a free good, therefore, implies that, for a majority, this basic need is fulfilled with little or no concept of value attached.

The greatest challenge facing most governments and planning departments is therefore in maintaining this perception without a price structure intervention. Governments can actively intervene with educational, promotional, institutional drives to sustainability (indirect subsidies comparable to "infrastructural developments" such as roads) and accept that urban populations may be within a fuelwood market. Active government intervention in the fuelwood market by way of price controls and direct subsidies etc would surely be a sign of failure. This is similar to price interventions on environmental issues and degradations.

All other considerations pale into comparative insignificance. As improved living standards are realized, increasing consumer demands and expectations are affected by price mechanisms. Each decision both at the household level and government level is made, to a large extent, on the relative cost of the options. From fuel switching in cooking to improved lighting, and choice of technologies in electrification in rural power the dictates of market prices and government interventions, if any, are the decisive factors.

For the grid connected consumer electricity prices should generally reflect costs of production. Utilities ought to be profitable, so as to help finance grid extensions and capital replacement, but should be government regulated. Tariff structure increases sought by utilities need to be carefully assessed, by consultants if in-country capability does not exist, and "capacity building funding" sought by engineers ought to be analyzed against the options of conservation etc.

The cost of oil in world markets and hence actual prices of derivatives are subject to fluctuations and uncontrollable. Assessment of alternative indigenous energy sources is essential; if a resource exists and can be viably developed long term intervention on the overall price mechanism, namely subsidies, can be avoided. However, intermediate policies such as elimination of a fixed meter charge or a lifeline tariff could be considered for low income consumers.

For non-grid extension rural electrification some capital installation subsidy is required but with operation and maintenance costs to be paid by the user. This ensures that, when a grid connection is made, users will usually have to pay less. Governments should maintain awareness of the existing level of subsidies in providing fossil fuels to the rural consumers. Minimizing freight costs by transport rationalization must be considered. Indeed fossil fuel prices etc. are only "managed" by government but in general reflect the activity in market prices. Hence government energy policy need not necessarily be concerned about pricing in a direct interventionist way. Government programmes for a sustainable fuelwood structure together with assessment and installation of non-fossil fuel base load grid supply and extension are therefore important areas for donor assistance. This assistance could be in the form of management assistance, (e conservation strategies and possibilities), training, (biomass sector) and grant aid or soft loan capital expenditure investment (eg. hydro plants, grid extensions).

WOMEN IN ENERGY: POINTS RAISED IN THE ELECTRIFICATION WORKING GROUP

1) Rural electrification design. The engineers/planners responsible for RE projects generally interview mainly (or only) the community men before designing the system. The group feels that they should solicit the opinions of all users and incorporate the findings into the designs.

2) Effective use of electricity. Rural electrification is often justified in part by improved opportunities for education because children can study better at night. For a rural community, the provision of regular lighting in school classrooms can be more important than lighting in homes if one of the goals is improved education. The planners should assure that school lighting is available in classrooms, not just teacher's offices and quarters.

3) Safety of electricity use. When rural electricity systems are commissioned, there is seldom any instruction for the women in safety, effective use of electricity or abuse of electricity. User education programmes should-be built into the planning process.

4) Urban household electrification. Women are expected to stretch the household budget but are usually unaware of the real cost of using various electric appliances. Education campaigns over the radio or the press have a limited impact. Utilities should regularly provide information to consumers on how to economize. They could consider a consumer relations officer who regularly speaks to women's groups on effective use of electricity.

5) Productive use of electricity in rural communities. When a village power plant is installed, information should be provided to the local women's association on possible uses of electric power for productive purposes. This should be a matter of liaison: providing information rather than promoting power use.

6) Lighting. Some household surveys in the Pacific have indicated that lighting is the highest priority use of electricity by women.

7) Electrification and donor policy. Nothing explicitly discussed regarding women's issues. Should aid-funded power programmes include support for some of the education issues indicated above.

Introduction

Issues identified by the WG:

* deforestation arising from fuelwood use
* smoke inhalation in kitchens
* global warming
* spillage of petroleum fuels
* environmental changes from building hydro dams

Strategies for addressing the problem:

deforestation -

* encourage the use of alternative fuels such as kerosene
* encourage reforestation
* protect access to fuelwood plantations
* encourage fuelwood conservation through the use of more efficient stoves
* environmental education for caring and management of trees in home gardens and village forests

smoke inhalation -

* improve cookstoves by using external vent (chimney)
* fuel switching to alternative fuels
* change cooking habits to optimise cooking times and better manage the cooking process

global warming -

* more concerted effort by countries of the region to influence countries which are the source of excess carbon dioxide

* action to protect the region's forests, seas and coral reefs which are important sinks for carbon dioxide

* better management of our absorptive capacity

oil spillage -

* tighten handling and storing of petroleum fuels to minimize spillages

* storage sites to be located away from environmentally sensitive areas

* prepare and use oil spill contingency plans

* tighten rules and strengthen enforcement regarding spillage and waste oil disposal, including that arising from interisland shipping

hydro dams -

* integrated plans for the management of hydro water catchments

* strict control on deforestation in hydro catchments

Specific Recommendations

1. Governments should be encouraged to develop policies which provide for environmental management of energy development along the lines recommended above.

2. All donor assistance programmes should be subject to independent environmental assessment.

3. Donors should target countries which are the main producers of excess carbon dioxide with a view to encouraging them to reduce emissions.

General Recommendation

The Working Group strongly urges that the PREA should go beyond the identification of problem areas and the listing of required actions, to suggest means for implementing those actions.

XII. BACKGROUND PAPER

OVERVIEW OF THE MICROHYDRO OPTION FOR RURAL ELECTRIFICATION IN PACIFIC ISLAND COUNTRIES

PEDP Report 1/

Introduction

Converting the energy in falling water to electricity hydroelectricity) is not an exotic renewable-energy technology; it has been in commercial use for decades. Where sufficient rainfall and suitable topography exist in an area of high power demand, hydroelectricity has proven to be the one of the most reliable power-generating technologies known. Although research continues into ways to reduce its initial cost, it is technically more robust, it is cleaner, it has lower operation and maintenance costs, and is less dependent on outside resources throughout its useful life than thermal competitors (namely coal and oil-fired steam generation in large power plants, diesel in small power plants).

Hydro power stations can be built in a huge range of sizes, from thousands of megawatts to less than 1 kilowatt. The largest hydro station in the Pacific region is the 80 MW Monasavu project in Fiji, and there are two stations of about 50 MW each in Papua New Guinea. These are owned by government corporations and serve the central urban grids. There are dozens of small hydro stations (microhydros) also operating in the region, some private and some government-owned, which serve communities, schools, missions, or commercial enterprises in remote isolated areas. Existing microhydros range from hundreds of kilowatts to less than five kilowatts.

Diesel is a far more common form of power in remote areas of the Pacific, of course, than microhydros. Diesels are common because they are easy and cheap to install (though not to operate) in remote areas; for all intents and purposes, diesels are the standard by which competing technologies such as microhydros are measured in this region. Where they are feasible, microhydros are technically better suited for remote areas than equivalent-size diesels. In particular, they don't require as many operators, they are less subject to breakdown, they can increase operation from 10 or 12 hours per day (typical of small diesel systems) to 24 hours per day at almost no additional cost, they have a longer useful life, and they can run for long periods without supplies from the outside world. They are therefore a valuable option for rural electrification in some Pacific Island countries. Microhydros are, however, very expensive, and they are not technically feasible in all countries or in all areas of any country. Microhydros thus have a limited but important role in rural development in the region.

1/ This paper is an expanded version of a paper prepared by Chris Cheatham, PEDP Power Sector Planner, for presentation at the South Pacific Commission Workshop on Rural Electrification (Brisbane, 7-8 September, 1988).

Constraining Factors

Capital Costs Are High

A hydroelectric power station requires extensive civil works for the water conduits, i.e. the intake structure, the head race, sandtrap(s), settling pond, and penstock. The power house, which is the main civil structure in most other conventional power technologies, is a minor cost component in a typical hydro.project. Aside from the civil structures themselves, hydro construction will often involve elaborate site preparation work (for example, roads and bridges built or upgraded, large areas cleared for fabrication of forms and pipes, etc.) to accommodate the heavy construction that follows. These comments apply particularly to microhydros. The size and cost of the structures required in a hydro power station do not reduce proportionally with reductions in its kW capacity: the cost-per-kw of a small station is higher than it is for a large one. It is safe to say that among technologies which are technically feasible for rural electrification in the Pacific region, including diesel, photovoltaic, grid extensions, and combustion of biomass in various forms, microhydros are probably the most expensive to install. If they nevertheless make economic sense as a tool for rural development, it is because the availability of local resources warrant them and their advantages during their operating life are enough to outweigh their initial cost. These circumstances exist in some areas of the Pacific, but not widely.

Local Conditions Are Difficult

To make matters worse, microhydros are more expensive in the Pacific than in most other regions of the world. The local geologic and geographic conditions are adverse to microhydro development because:

(a) the distance to a technically-favorable site from the nearest urban area is often great, such that most of the heavy materials and all of the electrical equipment, as well as the construction equipment (if needed) is transported to site at high cost;

(b) skilled labor is required - usually from overseas - throughout the lengthy construction period for a microhydro; if the site is isolated, the cost of maintaining skilled labor on site throughout construction is increased; and

(c) the poor soils in the region - mainly volcanic in the larger Pacific Island countries where microhydros are most likely to be feasible - require that water conduits be built with concrete lining or buried steel pipe, rather than the much less expensive open unlined canals that are possible in other parts of the world.

These factors contribute heavily to the cost of any microhydro project in this region. Whereas a 100 kW scheme in upstate New York (USA), where access is good, infrastructure well developed, and skilled labor plentiful, might be built for US$2,000/KW, costs five times higher have been experienced in this region. The cost of energy from microhydros recently built or planned in isolated areas of Pacific Island countries, when the amortised capital costs are included, is in the range of 30 to 50 US cents per kwh.

Paradoxically, it is these same adverse conditions that make microhydros economically viable in certain places in the region. Where the initial cost of a microhydro project is high due to inaccessibility of the site, the cost of diesel power will also be high because of the cost of transporting fuel, maintenance personnel, and spare parts. In the same places, grid extensions (which normally are a far cheaper means of supplying 24-hour power to a village than a microhydro) will not be feasible. A microhydro is often most attractive in areas where it is the most difficult to build. A microhydro construction programme in Papua New Guinea, for example, plans to construct two projects in sites where access is possible only by air.

The Economic Niche of Microhydros in the Pacific

The Economically Favorable Environment for Microhydros

Microhydros are never likely to compete economically with central-station hydros or diesels serving urban grids, since the capital cost of microhydros per kW installed is several times higher than larger, urban systems. There are, however, several distinct but limited conditions which define the "economic niche" of microhydros in the Pacific region.

(a) Microhydros are best suited for small, electrically isolated power systems serving a single village or at most two or three closely adjacent villages, because alternative power sources are also extremely costly and their reliability is often low. Microhydros have the very important advantages of low operation and maintenance requirements and high durability. Of course, the village or villages must have adequate natural resources for microhydro flowing water and suitable topography).

(b) Microhydros must be located in areas which have identifiable and non-subsidized loads, i.e., where power is consumed by users who pay the full cost. This condition is evident, for example, wherever a commercial enterprise in a remote area supplies its own power with diesel generators or other means, or power is purchased from another producer at full cost. This condition ensures that there will be a market for the output of the microhydro. If economic analysis shows that the microhydro is the least cost source of power for a village compared to the available alternatives, then the microhydro will produce savings for the consumers (and possibly higher quality power) and there will be an adequate cash flow to keep the system running.

(c) A successful microhydro project requires a sponsor - i.e., a person or institution who assumes responsibility for its construction, operation, and maintenance. In general, projects in the past have been successful only when there has been a local spearhead" to direct and manage the project, usually someone with a direct commercial stake in its success. Throughout the Pacific Island countries with hydro resources, there are examples of missions, agribusinesses, and hotels which have successfully built and operated microhydros for their own benefit, and have provided electricity (or services which depend on electricity) to people in the immediate area. There are examples of government microhydro projects which have foundered because they failed to provide a sponsor or to identify a private institution with sufficient interest in the output of the project to invest at least time and effort in seeing that it is commissioned and operated successfully.

The main conclusion of this section is that microhydros are likely to be economically attractive in isolated areas where there is already an identifiable load; in other words, microhydros will function best as diesel replacement schemes in rural areas, rather than means to bring electrification to non-electrified areas. This is not to say that microhydros are not an option for rural electrification, but they are an option only in a narrow sense of that term: replacing high cost, intermittent, and unreliable diesel power with continuous and generally more reliable hydro power. The benefits of rural electrification in this narrow sense are limited to what microhydros are best suited to provide: more electricity of higher quality, at generally reduced cost compared to diesel. In a number of areas in the Pacific region, microhydros can provide this kind of rural electrification benefit in a cost-effective way.

Microhydros and Photovoltaic

An implication of the foregoing is that microhydros should not be compared directly with photovoltaic as an option for rural electrification, because the two technologies serve very different purposes. Photovoltaic (in the Pacific Islands, a low voltage, DC power supply suitable mainly for lighting and battery charging) is perhaps the best means to introduce electricity to non-electrified villages: a photovoltaic system is simple to operate, reliable assuming that good-quality components are chosen can be size to supply the very low level power consumption typical of a newly-electrified (and entirely domestic) village, and can be expanded easily to accommodate growth in demand. Microhydros become a viable option only after power consumption grows to include commercial and social service loads, particularly for freezers and electric motors, because there will then be a requirement for reliable (and probably 24-hour) AC power. At that time, microhydros will be compared with diesels under prevailing fuel prices and transport costs.

Practical Considerations Before Establishing a Microhydro-based Rural Electrification Programme

The Institutional Problem

Most countries in the region have no rural electrification policies and few countries have developed full time staff to rural development planning. The ultimate benefits of a rural electrification project, its costs, and whether ii will work very well after it's installed, are not usually understood by the government before the project is approved. Not surprisingly, there is a lack of consistent policy regarding which institution should have responsibility for the projects to be constructed. Rural projects - both electrical and others - often fail in the first few years after construction simply because there was no entity appointed with full responsibility and authority to operate them on behalf of the government.

The institutional problems should be sorted out before projects are begun. The government should have a clear rural electrification policy from the outset which spells out, among other things, which government department is responsible for administering rural electrification projects, how projects will be selected, bow tariffs will be set, the degree of long term commitment the government will make to constructing and operating unprofitable power stations in rural areas, and which government department (if different from the rural electrification agency) is responsible for operating the projects during their useful life.

The Requirement for Administrative Manpower

The burden on government of administering a single rural electrification project, let alone a programme involving multiple projects, is much greater than most governments usually expect it to be. A rural electrification project is difficult to administer because the project is unusual; interest in rural electrification among Pacific island countries is, after all, fairly recent. This is especially true of microhydro projects, because each project must be custom-designed for its particular site, and the full-time attention of a project administrator is required for supervising the work and administering payments to contractors and consultants throughout the design and construction period, which (combined) can occupy three years.

Even a small microhydro project can force the diversion of substantial manpower away from the government's existing functions. Once a project is started, delays should be expected both in executing the paperwork for the project and in completing the government's routine work. If a project is assigned for implementation to a particular group in the civil service, for example the Energy Planning Unit, expect the Unit to accomplish little else except the project during the period of design, tendering, and construction.

The Need for Training

Once a rural electrification policy framework is in place, the most persistent constraint to a successful microhydro development programme will be manpower. It is never too early in the life of any programme to begin manpower planning and training. The objective of training should be to provide government with a core group of local engineers and supervisors capable of selecting projects, supervising consultants, administering construction contracts, and generally implementing the government's rural development policy.

The number of people recruited for the programme depends, of course, on the government's ultimate commitment to rural electrification. Skilled local manpower is an extremely scarce commodity among the Pacific Island governments; what skilled manpower exists is broadly applied in government's traditional high-priority areas, such as national planning, budgets, and foreign affairs. One of the unfortunate characteristics of a microhydro programme is that the skills required are difficult to attain but are rather narrowly applied; an engineer with five years' experience administering microhydro projects, for example, could not easily be transferred to Finance or national planning functions. The resources available for- training are sometimes also scarce. Therefore, the choice to allocate more resources to train people to implement microhydro projects is not an easy one, and it sometimes means that less training will occur elsewhere in government.

Any microhydro project, no matter how small, is likely to overwhelm a single professional, no matter how capable. At least two professionals are required for any project: one for overall management and coordination of the work with other agencies inside and outside of government, and another to concentrate almost entirely on contracts (preparing terms of reference and contracts for consultants, preparing construction tenders, administering contract payments, etc.). Where a programme is established to construct multiple projects, it is desirable to appoint a programme administrator with economic skills to oversee the project managers, have at least one (preferably two) contract specialists, and an engineer to carry out initial surveys and to vet designs.

Training for these positions should take place on-the-job, although it is recommended that the programme administrator (the senior position) be recruited with appropriate tertiary qualifications, and the contract specialist(s) should have previous experience. The project managers, contract specialists, and engineers should be exposed to all aspects of a project's development, from initial identification to detailed engineering, tendering, construction supervision, and commissioning. It is therefore important to recruit trainees for these positions early in a programme's, life preferably before it begins. During the training period (up to five years), trainees would:

(a) participate in the administrative functions of the programme's home office, under the supervision of the programme administrator;

(b) serve short term secondments in the overseas offices of consultants employed for engineering services for the programme;

(c) serve short term secondments at the construction site during critical stages of the work, particularly mobilization, construction of major works such as the forebay and laying of the penstock, installation of electromechanical equipment, commissioning, and any time when major design changes are required;

(d) pay short visits to the government offices in other countries in the region involved in similar projects; and

(e) attend appropriate overseas courses as they become available.

Survey Data

Of the territories and countries of the region which have hydro resources, only Papua New Guinea, Fiji, French Polynesia, and Western Samoa have undertaken systematic surveys of the extent of their resources in rural areas. The task of collecting resource data in the other countries, however, is not daunting, once the proper role of microhydros in rural electrification is appreciated by planners. Only those hydro resources adjacent to isolated communities which already possess a source of electricity, whether private or public, need be surveyed in detail. In most countries (Papua New Guinea the notable exception), such communities are not numerous.

The initial survey data for a selected community should consist of physical measurements of water flows, topography, and superficial geologic conditions. Further, a survey of the community itself should be conducted to determine the size and type of load existing and likely to develop there. Discussions should be held with local leaders and businesses to determine the extent of economic activity in the area. These data can then be combined into a preliminary proposal for detailed feasibility study and design of the microhydro project.

The professional staff in a microhydro development programme should be fully trained to carry out all initial survey work.

Regional Organizations Which Can Assist Training and Programme Design

Regional Network for Small Hydro Power (RN-SHP)

In May 1983, the Un-sponsored Regional Network for Small Hydro Power was established, supported by the ESCAP Regional Energy Development Programme (REDP). The purpose of the Network is to provide countries in Asia and the Pacific a means to exchange information and experience from research and hydro programme activities in the region. In addition, the Network sponsors courses in China for member countries to receive training in civil design, operation and maintenance, project planning, and related topics. Participants from several Pacific Island countries have attended training courses at the Hangzhou Regional Center (HRC) in China during the last few years.

Recently, there has been considerable effort to involve Pacific Island countries more closely in Network activities. The Network has recognized that the training needs of Pacific Island countries for microhydro development are quite different from their Asian counterparts, and that specialized activities will be required for the Network to make the same contribution in the Pacific as it makes in Asia. In particular, where microhydro programmes in Asian countries are large and already well developed, neither the programmes nor the policy framework for them exist in most Pacific Island countries. Microhydro sites in the Pacific region are generally less accessible than sites in Asia, and the geologic conditions are generally more difficult. Pacific Island countries need training in policy development, programme design, how to manage projects where access is extremely limited, how to obtain financial assistance overseas, and how to deal with difficulties with the physical environment in a cost effective way.

In September 1987, the Network organized a consultative mission to the Pacific sub region to visit Pacific Island governments and assess their interest and special needs for services of the Network. The mission found considerable.interest in microhydros among the countries with hydro resources which were visited 2/ although the countries lack manpower to even begin planning microhydro programmes. The mission recommended that:

(a) the 1988 meeting of the Network executive committee (the periodic Technical Advisory Group or TAG Meeting) be held in Fiji to ensure the widest possible participation by Pacific Island governments; and

(b) that more resources be sought through member countries and international organizations for training and related activities designed specifically for the Pacific Island countries.

The 3rd TAG meeting was held in Suva in June 1988. The Meeting agreed that for 1988, 1989, and 1990, training courses would be provided in China and the Philippines in the socio-economic aspects of microhydro development, planning and design guidelines, construction management, local manufacture of equipment, watershed management and environmental impact assessment, and unmanned remote operation of microhydro systems.

Further, the Network Secretariat was requested to begin discussions with European governments and other potential donors to enable an expansion of Network activities. Specialized courses will be designed for ground-level topics such as practical approaches to site identification, preparation of financial proposals for projects, estimation and evaluation of hydrological data (with minimum data available), planning and design of transmission and distribution systems, and others.

PEDP and the Forum Secretariat (SPEC)

The United Nations Pacific Energy Development Programme (PEDP) provides advice to countries in the region on a wide range of energy sector activities including microhydro programme design and project evaluations, on request from the governments. Following the annual Regional Energy Meeting in September 1988, PEDP and the Forum Secretariat have adopted a joint work programme. During 1989 and 1990, it is hoped that the two organizations will jointly administer a GTZ German aid agency) funded renewable energy programme which will have a large microhydro component, including policy development for microhydro programmes, in-country resource assessments, training courses and workshops, and some hardware assistance to future microhydro projects.

2/ Fiji, PNG, Sclomon Island, and Vanuatu

RURAL ELECTRIFICATION ISSUES WITH PARTICULAR REFERENCE TO THE PACIFIC ISLANDS

PEDP 1/

Preface

In June 1988, PEDP organized a "Training workshop on the Socio-economic Impact of Rural Electrification in the Pacific islands" in Suva, Fiji. Among the background discussion documents prepared for the workshop was the present paper prepared by Dr Gerhard Herrmann, a consultant with wide experience in electric power sector planning, analysis, tariff policy and management. Dr Herrmann previously carried out a number of assignments for PEDP within the Pacific Islands and is aware of the characteristics of small island power systems.

This report provides very useful guidelines for national energy authorities and power sector planners. It deserves wider distribution than to the few people who were able to attend our workshop. Therefore, PEDP is pleased to issue and distribute this slightly edited version of Dr Herrmann's analysis.

Introduction

There is a substantial volume of literature on Rural Electrification (RE), since it is a subject that has regularly been encountered by many development agencies. Exhaustive studies have been funded, some dealing with the subject in general, others looking at the situation in individual countries.

Unfortunately, the planner will find little guidance towards the formulation of a coherent RE policy in the documentation, except perhaps in highlighting some of the difficulties that are likely to be encountered.

While studies have been conducted at considerable cost, both in time and money, and reports are, no doubt, presented with the best of intentions, it appears to me that the authors frequently do not draw the correct conclusions from the evidence that they have collected, or permit themselves to be unduly influenced by a comparison between observed living conditions and their own. If the concern of the writer of a report (or that of his employers) is for the sociological benefits of RE, there is a tendency to highlight these and to minimize the economic issues, and vice versa. There have certainly been some far reaching policy changes over the years in agencies such as the World Bank, and anyone wishing to further a particular point of view will have no difficulty in finding reports to support his ideas.

There also appears to be a lack of realism in expenditure projections and in assessing the cost of and need for servicing and technical know-how. The fact that some students and/or unpaid assistants were able to install electrical service and connect up 20 houses for $X does not

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provide a realistic basis for a nationwide RE policy, and to give a few week-training and some tools to an operator of a diesel engine who has no previous mechanical knowledge and training (recommended as a means of reducing costly service calls), is almost certainly a recipe for early disaster.

The objective of these notes is to provide guidelines for government energy planners in a Pacific island environment to permit them to make recommendations for the formulation of a reasoned RE policy. This will require the following:

(a) Analyzing those aspects of RE that have presented, or are likely to present, problems;

(b) Identifying conflicting socio-political and economic considerations;

(c) Suggesting the type of consumer an RE policy should cover;

(d) Considering the institutional aspects of administering both development and continuing operation of a policy of RE;

(e) Attempting, in general terms, to isolate and to quantify the costs involved; and

(f) Suggesting whether, and to what extent, these costs should be borne by the policy's beneficiaries.

Summary

(a) A perusal of literature on rural electrification (RE) indicates that conclusions drawn are frequently contradictory and not in agreement with the evidence presented.

(b) From evidence put forward in various reports it appears that, at least in Pacific island countries, RE is not accorded a high priority in the view of rural villagers. Water, roads and other services apparently are considered to be of greater importance.

(c) In order to ensure a reasoned approach toward the formulation of an RE policy, a planner will have to address a number of difficult topics in his recommendations, among which the accurate determination of both capital and recurrent costs is particularly important.

(d) Technical issues are discussed in relation to the three main components of RE, i.e. the extension of the public utility network, where this is possible; self-contained systems with diesel generators; and individual photovoltaic (PV) system.

(e) Costs are discussed in general terms, classified as demand related, energy related and consumer related, and also to highlight the cost differences between urban and rural consumers.

(f) An annex provides a cost analysis of a basic rural diesel installation, which can be used as a spreadsheet template. It indicates the high level of costs that may be involved, and permits comparison with the costs of using PVs.

(g) Three types of rural consumers are defined in relation to the costs incurred in supplying them and the RE options available.

(h) Attention is drawn to the subsidies likely to be involved in the supply of electricity to rural consumers under an RE policy. Both capital and recurrent subsidies may be involved. The paper stresses the importance of quantifying subsidies on the basis of accurate costs, so as to ensure that there is adequate provision for these.

(i) Two usual sources of subsidies for rural consumers are discussed: The government and other consumers. Urban consumers often are not aware of the fact that they are subsidizing rural consumers, and this may be intentional or incidental. The author urges that both those subsidizing and those being subsidized should be aware of the fact.

(j) The main danger of subsidies is the potential for waste that arises when the price of goods and services does not correctly reflect the cost of the resources used in producing them.

(k) Proposals are made to limit capital subsidies to a maximum amount per rural household connected, with the consumer required to provide a proportion of the capital cost. It is suggested that the supply of electricity to consumers whose connection is subsidized should be restricted for five years by means of a load limiter.

(l) Proposals are also made to limit both rural and urban subsidies on recurrent expenditure by limiting the number of kWh available at subsidized rates and by applying minimum charges corresponding to savings made by consumers in expenditure on other lighting sources.

(m) The adequate administration of a RE programme in the planning, construction and operating stages requires a suitable institutional framework, for which provision should be made in any recommendations for RE.

The Problems of Rural Electrification

In reading through reports of RE projects and proposals there appear to be certain aspects that present particular difficulties both in the formulation of an RE policy as well as in its subsequent administration:

(a) A fundamental problem arises from a tendency of not differentiating clearly between the strictly economic issues and the philosophical and socio-political ones, and of not making it quite clear what sort of consumer is to be covered by an RE policy. As long as there is no clear understanding of why there should be RE and who is to benefit from an RE policy, it is impossible to say with any degree of certainty what benefits will accrue and what costs will be incurred.

(b) The next problem to be resolved, which again depends on the why and who of RE, as well as on various other factors, is the standard or level of electrical service that is necessary and appropriate, bearing in mind the possibility (particularly in a Pacific island environment with widely varying degrees of isolation), that standards and levels appropriate to one locality may be quite unsuitable for another.

(c) The next, and in practice one of the most important and difficult, considerations is in regard to costs. Any policy recommendation must spell out in detail and on a realistic basis the costs that will be incurred in providing RE. Not only individual and total costs are required, but proposals as to the time frame within which they are likely to be incurred, the apportionment of costs between government and potential consumers, and the extent of any continuing financial commitment both by government and the rural population. It appears from reports of completed projects that one of the reasons why a substantial proportion of rural consumers have not been satisfied with the service they have received, is that they had not appreciated the need for, or extent of, continuing expenditure. In consequence, as revenue was less than had been projected, the subsidies required from governments have been greater than expected.

(d) Although the underlying technology of electricity supply for RE is no different to that applied in providing electricity to urban consumers, considerable savings can be made by accepting less onerous standards of line construction and/or wiring. In isolated systems the maintenance of small high speed diesel engines presents an organizational challenge, and a technology that differs materially from that of large slow speed machines as used in urban power stations. The technology of photovoltaic (PV) electricity generation will be relevant in the framework of an RE policy, and also requires appropriate expertise.

(e) If there is to be an avoidance of unpleasant surprises for both government and potential RE consumers, projects will have to be planned and costed on an individual basis, and this will require at least one preliminary visit to each PE site. It also appears from reports that not enough attention is given, neither in advance nor on completion of projects, to tariffs apportioning operating costs among beneficiaries of RE systems, as well as to the collection of amounts due from consumers. All these activities are part of the planning and operating procedures relating to RE - they require the provision of suitable skilled staff in an appropriate institutional environment, and incur costs.

A paper entitled Policy Guidelines on Rural Electrification : Substantive Report" by Bowman and Pintz (see Annex A) sets out the conclusions of a meeting on RE that dealt specifically with the Pacific island region. It is probably known to most readers. In references to this paper its name will be abbreviated to "The Guidelines".

The Philosophy of Rural Electrification

In most developed countries all, or at least a large majority, of the population have access to a public supply of electricity, although in some, such as Spain, the general availability of public electricity supply has come about quite recently. This ready access to public electricity supply has been facilitated by two factors, viz. high population density and the relatively small proportion of the population living outside of urban areas. Furthermore, in those countries with a relatively large rural population, such as France and Spain, the tradition has been for the rural population not to live on their farms, but in small, densely populated villages, thus materially reducing the costs of electricity distribution that would have been associated with supplying numerous isolated farm consumers. With some exceptions, electric utilities in Europe are government enterprises, and socio-political considerations have played an important role in formulating RE policy.

In the rural USA, on the other hand, which contains large, sparsely populated areas, electricity supply has traditionally been mainly in the hands of private enterprise utilities. These are "regulated" by state electricity commissions which are required to ensure that tariffs are cost orientated and avoid cross-subsidization, i.e. subsidization of one type or group of consumers by another or others. (After many years of uncertainty as to what definition Of costs is relevant in this context, recent emphasis has been on marginal costs).

Prior to the setting up of the Rural Electrification Administration (REA), this policy effectively restricted the supply of electricity to urban consumers. Despite the generally high electricity consumption levels of US consumers and cost effective (though often unsightly) construction methods of electricity distribution systems, not only individual farmers, but even rural villages, could not afford the connection fees and tariffs that would be needed for economically viable electricity supplies.

The REA was set up in the depression years of the 1930s by the US Government to alleviate the plight of the rural population, and has succeeded in materially expanding electricity supply to rural communities. This has not been possible without subsidy, but this is limited, and within the framework of the subsidies provided, the service is required to be economically viable. The main subsidy is in the form of low interest rates on loans for the acquisition of capital assets, and there is also free advice on the planning and operation of small electric utilities. Only the interest element of recurrent expenditure, therefore, is subsidized, and only until loans have been repaid.

It is interesting to note from this example that, even with the high levels of consumption that are typical of US electricity consumers, some degree of subsidy is usually required to get RE started.

In most Western European countries with publicly owned electric utilities there is an acknowledged, but indeterminate subsidy of rural consumers both in the capital cost of connecting them and on a continuous basis. This typically takes the form of uniform connection fees and uniform tariffs. Since both capital and operating costs are materially higher for rural than for urban consumers (as will be noted later), the application of uniform charges and rates indicates that rural consumers are being subsidized by their urban counterparts. The extent of the subsidy is difficult to assess, and this may be intentional or incidental. In Spain, where electric utilities are in private hands, there is also a national uniform tariff, but connection fees for isolated rural consumers are so high, that few of these can avail themselves of the operating subsidy resulting from the uniform tariff. On the other hand, in terms of Franco's motto "Bread and light for everyone", state subsidies on capital expenditure have encouraged the connection of a majority of rural villages to the national grid.

The financial effect on an individual urban consumer of a policy of subsidizing rural consumers in developed countries is usually small, but the corresponding situation in developing countries is quite different. In these, the proportion of urban dwellers is much smaller, and more importantly, consumption levels, both urban and rural, are likely to be much lower. In such circumstances ad hoc cross-subsidization can soon produce financial chaos, and the absence of a definite and realistic RE policy can cause financial embarrassment and much resentment.

The process of planning presupposes an ideal or model towards which Planning is directed, and for many planners the general availability of electrical services is an integral part of this ideal. Why should the inhabitants of a remote village or island, or an isolated farmer, be denied the benefits of having electricity which are available to those citizens living in towns? Why, indeed? And if the rural inhabitants cannot afford the full cost of providing them with electrical service, is it not the obligation of the state (i.e. the community at large) to make available a subsidy for this purpose? The same questions may be asked about the universal availability of good water supplies, roads, public transport, health services, adequate - if not good - housing, even radios, TV, motor cars, refrigerators, shops and cinemas.

The essential answer is, of course, that countries simply do not have the economic resources to provide all their citizens with an equal degree of welfare and economic goods, even though it may be their political philosophy to do so. It is necessary, therefore, to apportion the limited resource that are available for the maximum welfare of the community, and to establish priorities for this purpose.

Let us look at some reasons quoted in support of giving priority to RE in the allocation of scarce financial and other resources:

(a) It is an important, or the most important, priority of rural communities. This, if correct, would certainly be a most persuasive argument, and is discussed in some detail below. It may be noted at this point that "The Guidelines" states that RE "enjoys a high political priority and is desired by rural residents", but subsequently states that "... rural pacific islanders with access to RE have identified adequate water supplies, sanitation, housing, transportation services, education facilities, and credit and extension services for agricultural projects as being of more importance than RE". A similar contradiction may be found in the "Fiji Rural Electrification Study" quoted in Annex A.

(b) Various authors have claimed that the availability of RE improves the quality of rural life, and have seen this either as an end in itself, or as a mean of diminishing the drift of the rural population to the cities. There does not appear to be any statistical evidence to support the latter claim, neither in the Pacific island region, nor elsewhere. While "The Guidelines" states that "Rural welfare should be regarded as a legitimate objective of RE ..." in order to improve the quality of life, a subsequent statement suggests that the "perceived higher priority community needs", detailed in the previous paragraph should be satisfied before a village is considered for RE. That would certainly give a very low priority to RE.

(c) Claims are sometimes made that RE will enable the rural population to increase its cash income, but few rural activities are, in fact, suitable for the application of electric motor driven machinery or other applications of electricity. The major exception is water pumping, which has been used as the primary justification for much of India's very extensive RE programme. (In practice, it seems, many rural Indians have reverted to pumping with diesel engines as electricity supplies were too unreliable, presumably due to either poor construction of power lines or overloading.

"The Guidelines" agrees that in the Pacific region RE is "... rarely used to increase rural cash incomes."

(d) In various countries RE projects were undertaken in the belief that they would assist in the development of rural areas by encouraging the decentralization of industries into rural areas. In view of the small proportion of total costs accounted for by electricity costs (commonly about 5% rarely as much as 10%), it would be surprising if the availability of electricity, even if at particularly favorable rates, would influence the sitting of factories, and this author is not aware of any convincing claims that a policy of RE has been an important factor in influencing the location of new industries.

(e) It is also claimed that the availability of electricity in schools will help to improve standards of education. It is unlikely that rural school children will wish to spend their evenings in the electrically lit classroom, and any improvement in educational standards can only be attributed to RE very indirectly, in that the availability of electricity may attract the better teachers into rural areas.

It would seem, therefore, that the major motivation for RE is in satisfying a priority of the rural population, as perceived either by rural villagers or by politicians or by the civil service and its advisers. Unfortunately the identification of priorities is not a scientific process, and at best, will involve subjective judgments, which inevitably will be influenced by the priorities of the persons recommending or implementing a policy. It is possible that outside consultants or representatives of donor agencies who normally live in a totally different environment, and to whom a life without electricity is almost unthinkable, might exaggerate the importance of RE to the inhabitants of a rural Pacific Island village.

The villagers, on the other hand, having neither roads, nor water supplies, nor electricity, may take a very different view, and this has been found by several researchers. The priority expressed by the villagers may, however, also be misguided, since they are being asked to choose between roads and water and medical services (for instance), which they know and have used or experienced (and have perhaps found inadequate), and electricity, of which they may have no personal knowledge. The expressed priority may then be that of one or two persons, and not the consensus of the inhabitants of the village.

The selection of a priority may be further complicated by differences in the cost of providing and maintaining various services. If the government has a certain amount of money available, and if the average cost of RE per consumer is, say, three times the cost of providing running water, the government would probably prefer to provide the cheaper service to a larger number of its citizens, whatever their individual priorities may be.

Taking a realistic view, the decision as to whether or not to embark on a policy of RE may ultimately be a political one, since to the government of the day it is the sum of satisfied individual priorities that is paramount, as it is by these that the government's performance will be judged. But the decision will be influenced materially by projected costs, and by a comparison of the costs of RE with those of satisfying other rural needs. An accurate assessment of costs is therefore a precondition for logical decisions.

There are difficulties involved in determining such costs. In part these may be due to the fact that installations in isolated rural areas have in the past been undertaken in a particular country by a government department, and the extraction of true costs in the commercial sense from government records is difficult, if not impossible. Electricity undertaking, on the other hand, traditionally have been concerned with average costs, and while marginal cost concepts are of increasing importance, normal accounting records will not readily permit determination of the difference in the cost of connecting or supplying urban and rural consumers, even where this difference is quite substantial.

Because of the importance of costs in the decision process, and since these can also provide us with a means of defining the difference between rural and urban consumers, we will need to take a close look at electricity supply costs, but we shall first consider some technical aspects of electricity supply.

Technical Considerations

Electricity is not purchased for direct consumption, and before the occupants of premises can become electricity consumers four requirements must be met:

(a) The building must be wired to provide points at which electricity can be used. There are (or should be) wiring standards according to which the premises must be wired. The provision of protective devices and of a point at which electricity can be connected are normally considered part of the wiring installation. Before electricity is connected it is usual for the supplier to satisfy himself that connection of the premises will not interfere with his system, and for the safety of the consumer either the supplier, or a government inspector, may also be required to inspect the premises for compliance with wiring regulations.

Wiring regulations are drafted to cover all sorts of installations, and the cost of wiring a modern house can represent a substantial proportion of total building costs (typically between 3% and 8%), depending on the extent to which electrical appliances are to be used, the complexity of the installation and the severity of the wiring code. It is often suggested that some of the requirements of wiring regulations should be dispensed with or relaxed where small rural consumers using electricity only for lighting are concerned, but it should be remembered that the principal objective of the regulations is protection - of the consumer (against electrocution) and of the premises (against fire). Electric power supplied to small consumers is no less dangerous in regard to these risks than that supplied to larger ones.

The application of wiring codes to rural houses, particularly those to be found in rural villages in developing countries, is a thorny problem. Inspectors of electrical wiring are in a quandary, as they are urged in their training to insist on strict interpretation of wiring codes, and failure to do so could make them legally liable for an accident, even a fatality. The wiring codes, on the other hand, drawn up to provide for conditions in large cities, do not envisage their application to "bush houses" or "leaf houses", which in those cities would not even be regarded as temporary buildings. Compliance with wiring rules would require, at the very least, the provision of an expensive earth leakage circuit breaker, which would add materially to the total cost of a connection.

While it may be possible to relax or modify regulations, this should not be undertaken without reliable technical advice. It will normally involve the design of a wiring system suited to the type of rural house that is usual in the area, in which only basic lighting is envisaged. Education of consumers, making then aware of the danger of interfering with electrical circuits, is also necessary.

The remote rural consumer also faces a difficulty, since there is no suitably skilled person in the vicinity who can, and is authorized to, undertake the wiring of his house. If, as recommended in this paper (see below), the cost of wiring rural houses is regarded as part of the total cost of the service connection, the solution would be to have the houses wired by the team that is in the village to install the generator and its associated distribution system.

(b) There must be an appliance, which in its simplest form consists of a lamp and a switch controlling it, but may, of course, be a radio, TV, iron, cooker, refrigerator, water heater, kettle or any of the many electricity consuming appliances with which the market is flooded. Lights, and perhaps a radio, are the appliances normally used by even the smallest consumer, and both involve very little consumption. At the same time, the use of electric lights displaces other light sources (candles, pressure lamps, lanterns), which generally are less convenient and involve regular expenditure. Typical lighting costs in the Pacific area for fuel (kerosene or benzine) and lamp maintenance and replacement appear to be around US$6 to US$9 per household per month, although there are reports of households where this expenditure is $3 per month and even less. Where a radio is in use there will be additional savings on expenditure on batteries, which in some communities can make up a substantial part of the household cash budget.

(c) There must be a distribution system - a minimum of two (for single phase) and a maximum of four (for three phase) conductors which take the electricity supply to the various buildings from a central distribution point. The connection could be overhead, with poles that normally carry bare (i.e. uninsulated) conductors on insulators or by means of underground cables which should have a protective outer covering to minimize the risk of accidental damage. In a typical urban distribution system the cost of an underground installation is between three and five times that of overhead distribution. This ratio, as well as costs as such, vary over wide limits and depend very much on consumer density and the size of the system and of the consumer. Where distances are very short and poles are not required for street lighting, underground distribution may even be less costly than overhead, the more so if construction standards that are usual in urban electric utilities, such as placing cables 600mm or more under ground, are relaxed.

This is an area in which considerable economies can be achieved without lowering of safety standards, although they may well result in reduced reliability or voltage levels. Both electric lamps and radios are relatively insensitive to low voltage, (but note that the life of incandescent lamps is severely reduced by excess voltage, while electric motors are affected also by low voltage). Urban consumers supplied at a nominal 220 to 240 volts in what may be termed the European distribution system are usually not more than 600m from a distribution transformer, but where consumers are known to use electricity only for lighting, this distance can be increased substantially. On the other hand, where there is a high voltage (HV) supply already available (see next section), it may be more economical to supply consumers from more than one point than it would be to extend low voltage (LV) lines. The North American distribution system under which consumers are supplied at a nominal 110/115 Volts is less well suited to small systems and to the economical supply of very small consumers, particularly when these are not close together.

Poles represent a major cost component of distribution lines, and it is surprising that no Pacific island country apparently produces its own wooden poles, preferring instead to import these (or steel poles) at considerable expense from Australia or New Zealand. When the author was in Zimbabwe (then S. Rhodesia) in the early 1950s that country's electricity supply commission had a very ambitious RE programme but not much money and no proper plant for the treatment of poles. For many years poles were treated by boiling several simultaneously in long locally made steel tanks in the usual anti-termite mixture of creosote and diesel oil (in the Pacific area PCP treatment would perhaps be better). The poles were inexpensive, as forest waste was used to heat the tanks, and very few failures from termite activity were experienced.

Various species of Eucalyptus and one or two species of pine are widely used for overhead line poles in African countries, and if the correct sizes are selected for wind loading and wind velocity, they will perform as reliably as poles made from other materials. The author has noted, however, that wooden poles are set in concrete in some Pacific island countries. This is not advisable, as poles tend to rot under these conditions. Even when there is an economic advantage in using concrete poles, these are less likely to break in high winds when not placed in concrete. They may tend to lean after high winds, but it is quicker and less costly to straighten them than to have to replace broken poles.

Overhead lines may be damaged, or their operation affected, by winds, by lightning and by falling trees or branches - problems that do not affect underground cables. On the other hand, faults in an overhead system are easier to locate and repair than those in underground cables. The use of insulated overhead conductors is at times encountered in Pacific islands, and while their use will eliminate interference from trees and other vegetation, it will increase costs substantially. Not only are conductors more costly, but pole sizes have to be increased or more poles used) because of the increased wind resistance. The use of insulated overhead conductors is justified only where continuity of supply is essential.

(d) There must be a source of electricity. In most cases this source will either be a transformer with a length of HV transmission line connecting it to an electric utility's HV system, or a local generator, probably diesel engine driven, (or occasionally powered by a water turbine). When not connected to a network, local generation (often referred to as auto generation) will normally be at LV (i.e. the voltage at which power is supplied to the consumer), and the cost of providing more than one distribution point then becomes very high, as both step-up and step-down transformers and associated protective gear are required.

The cost of small transformers and generators is disproportionately higher than that of larger ones, but the use of larger units in anticipation of future growth usually is not viable, as there are increased transformer losses in the one case, while in the other, diesel engines become notably less efficient and more troublesome when operating at less than half of their rated capacity.

Electricity is usually metered, the charge for electrical energy used being based on the consumption of kWh or "units". There may also be a charge for the electrical demand in kW. Large electric utilities have many generators, and as these have different efficiencies according to type, age, motive source and loading, both average and marginal electricity costs vary according to time of day and season, determined by the machines used to cover the demand at any particular time.

Very sophisticated metering devices are available that can determine the consumers' demand and consumption at any moment of time or at regular intervals (e.g. every 15 minutes), but these are expensive and used only for very large consumers with monthly electricity bills of thousands of dollars. Since the cost of metering must clearly be such that the metering process does not add materially to the cost of what is being metered, most small consumers (i.e. those using, perhaps, less than 3000 kWh per annum) will probably have their consumption metered by a normal domestic type kWh meter. This imposes a fundamental limitation on the effectiveness with which any tariff applied to such consumers can reflect costs, and since only total energy used between meter readings is registered, only the average of costs can be recovered.

To improve the accuracy of cost recovery, there are other means available to differentiate between the load imposed by larger and smaller consumers such as the use of load limiters (see Annex B) or demand indicators, but these still do not provide a mean of indicating to a consumer that production and delivery costs are higher at certain times of the day and year than at others. This is possible only with kWh meters that have several counters (usually two or three) which can be activated by a time switch and permit the application of different rates at peak and other times. The high cost of such meters and time switches makes them (and hence time based rates) unsuitable for consumers using less than about 5000 kWh per annum. This, in turn, encourages the continued use of average, rather than marginal, pricing in the industry.

Electricity tariffs applied in various Pacific island countries may be found in Annex C, but the author would not recommend their application in RE proposals, as many are known to be heavily subsidized, and tariffs should be designed for specific applications on the basis of a determination of the costs that are to be recovered.

The discussion thus far has concentrated on what may be termed traditional sources of electricity, produced in the first place by a prime mover that may be a steam or hydraulic turbine or diesel engine, coupled to a generator. There is a further source of electricity that is particularly suitable for small consumers, and that is a system in which electricity is generated during daylight hours from a panel made up of a number of photovoltaic (PV) cells, and stored in a rechargeable battery for subsequent use.

Such PV systems have already been used in many Pacific islands, but because of the lack of reliable information on operating and maintenance costs, as well as on the causes and extent of failures experienced, they are still regarded as experimental by many governments and electricity authorities, although they are widely accepted as a source of electricity in isolated areas of many countries e.g. Australia. As PV systems, within their limitations, appear to be the least cost solution to providing lighting (where justified) in rural situations, a useful aid to RE policy decisions would be a reliable study of PV system in use (and of those that have failed), and PEDP has informed the author that it intends to continue and intensify its study of such systems during 1987.

A major criticism of PV installations is that only lighting (and the use of a radio) is available at relatively low cost. Lighting is, of course, the electricity application with the highest use value and is also an application where expenditure on electricity replaces an existing cash expenditure (the next in importance is likely to be the saving on batteries for radio use). There may also be an economically justifiable requirement for refrigeration (for instance to preserve meat or fish) which is often quoted as the reason for giving preference to autogeneration over the use of PVs. Refrigeration can, of course, also be provided from solar panels, but the capital cost is high. On the other hand, refrigeration can be provided at much lower capital cost for both domestic and small scale industrial use, and with a minimum need for maintenance, with kerosene operated refrigerators or deep freeze chests of the absorption type.

Since there must be a widespread demand for such refrigeration equipment, not only in the Pacific islands region, but also in parts of Australia, it is surprising that such units are apparently only available as imports from Sweden at very high costs. If energy planners could combine to encourage local manufacture (which is not very complicated) in the region, this may indirectly give a boost to the use of PV systems and allow a reduction in per consumer RE expenditure.

In view of a possible conflict of interests, it may also be good policy not to encourage electric utilities to get involved with PV systems. At the voltage used in PV system where appliances usually operate on 12V or 24V, there is no need to restrict installation to qualified electricians, as required in the case of 110V or 220V installations. Governments should also avoid direct involvement in the provision and installation of PV systems, and part of an RE policy might be to encourage private enterprise to promote the wider use of PV systems. In practice there will have to be involvement at government level in administration and advice, in channelling foreign aid, in establishing PV policy e.g. on subsidies - discussed later), and in ensuring the application of adequate quality standards to equipment supplied.

Costs

In order to distinguish between those electricity costs that are common to urban and rural consumers and those additional costs that are incurred only in supplying rural consumers, it is necessary to look in some detail at the components of the total cost. In doing so it must be remembered that, except for very large consumers, there is no point in deriving the cost of supplying any particular consumer, as we cannot apply a tariff to reflect this cost without using very expensive metering equipment. Accordingly, consumers are divided into categories or classes, and the costs of supplying all consumers in each category are averaged. The categories will depend on certain common characteristics, which result from the purpose for which electricity is used e.g. domestic, commercial, industrial) and the voltage at which the consumer takes supply. These characteristics determine the time and pattern of use, as well as the incidence of demand peaks, and their main influence on costs is due to the coincidence of these demand peaks.

It could, of course, be argued that there is as much reason to differentiate between those urban consumers living within 1km from the power station and those living further away, as there is to distinguish between all of these and a rural consumer. We find, in fact, that the borderline between rural and urban consumers cannot be defined in absolute terms, but also depends on certain consumer characteristics. In essence the distinction is based on deviations from average costs, but judgement as to the extent and frequency of such deviations required to justify a separate category of rural consumers will remain to some extent subjective.

Three basic cost components may be recognized in electricity supply:

(a) Fixed costs related to the maximum (electrical) demand (MD) that consumers jointly impose on the system;

(b) Variable costs related to the production of energy and those that are in delivering it to the consumer; and

(c) Fixed costs related to the number of consumers and their location.

MD Related Costs

These are primarily the costs resulting from fixed assets, their purchase and installation or construction, their financing and their eventual replacement with similar or larger or technically superior units. Such capital assets include generating plants, transformers and switchgear, HV transmission and distribution lines, LV lines and cables, and terminate with, but exclude, the consumers' service connections. The investment in transmission and distribution equipment is likely to be at least as large, and often much larger, than that in a generating plant. The cost of supplying consumers increases with their distance from the power source, and the lower the voltage at which they are supplied, the greater the cost. The proportion of total costs represented by fixed MD related costs also depends on these factors, as well as on the motive power source, and will be greater for hydro generation than for generation from fossil fuels.

If we consider first rural consumers that are connected to an existing electricity network, the costs we need to identify and quantify are the additional costs incurred only in the supply to them. Up to the point at which the supply to rural consumers leaves that part of the system common to both rural and urban consumers, fixed costs are (or are regarded on average as being) the same for all consumers taking supply at the same voltage. The additional costs will be the fixed costs of constructing, financing, operating and maintaining the transmission and distribution system beyond that point.

Some of the costs may be joint costs, shared with other rural or peri-urban consumers sharing some or all of the same facilities. Those fixed costs representing the interest on capital and the depreciation of assets will be reduced by the proportion of such costs contributed by consumers in the form of a connection fee, to the extent that this exceeds the actual cost of the service connection (see below). The balance, which would have to be financed by the public utility, would incur annual financial costs of about 7% of the current replacement cost of the assets in use, assuming an interest rate of 5% above the inflation rate, and a typical asset life of 25 years.

It should be noted that this is not a constant percentage, but it depends on the inflation rate, interest rate and asset life selected. As there is a negative net contribution to the sinking fund in the early Years, interest is charged on the negative balance at the same rate as on the original investment. It should also be noted that the sinking fund is not intended to provide the cost of replacing the asset, but only for the repayment of the original ivestment. The extra interest provided during the life of the asset by adding the rate of inflation is intended to compensate the investor for the erosion in the value of his investment.

Even if all capital costs are provided by consumers or by capital subsidy, this does not eliminate the fixed costs of operation and maintenance of the additional distribution system, typically amounting to 1.5% to 2.5% per annum of the current asset value. Provision must also be made for the replacement at the end of the economic life of those assets not funded by the utility.

If a sinking fund is set up for this purpose, then on the (economically correct) assumption that such a sinking fund will earn interest (taken again as being 5% above the inflation rate), and that the assets have a 25 year life, the annual contribution should be about 2.1% of the current replacement value of the assets in each year. The total annual fixed costs would then be between 8.5% and 9.5% (7% + 1.5% to 2.5%) of revalued assets financed by the utility, and between 3.6% and 4.6% (2.1% + 1.5% to 2.5%) of revalued assets financed by the consumer.

Prices should reflect the opportunity cost of capital used in the production of goods and services, and if this is to be the case, the costs to be recovered each year should be based on the replacement value of the assets in use and not on their historical costs. In practice it would be time consuming and unproductive to determine the replacement cost of assets each year, and assets are revalued by means of a formula or index, but the intention of public utility pricing is to base prices on marginal, rather than on historical, costs. In the presence of inflation this will have the effect of steadily increasing the asset base on which the costs are calculated.

The fixed costs incurred in distributing the output from a diesel generator or micro-hydro to an isolated rural community are essentially similar to those discussed above, but in this instance we must look at total costs - either to be able to compare these with the corresponding costs in an urban system (to determine the shortfall in revenue if there is to be a uniform national tariff) or to establish the level of rates required to cover total costs.

The principle of recovering capital cost plus interest over the life of a generating plant is the same as for distribution equipment, but the life of a diesel plant is much shorter, and fixed operating costs are higher as a proportion of asset value. Most maintenance costs of generating plants are primarily energy related, whereas those in distribution system are usually regarded as time related, and hence fixed.

Energy Related Costs

Both generating and distribution systems have energy related costs, i.e. costs that vary with the amount of energy produced or supplied to consumers.

The most important energy related cost of diesel generation is, of course, the cost of the fuel used, but most of the maintenance costs of the engine are also output related, although the relationship is less predictable than in the case of fuel. Whereas maintenance costs of large diesel machines can be taken as being entirely output related, they tend to take on the character of fixed costs, related more to time and cost of plant, in the case of small high machines.

The variable costs of the transmission and distribution system are the result of energy losses in lines, transformers and cables, which are related to the energy transferred. Most of these losses (some transformer losses are the exception) vary as the square of the current, and the level of losses is therefore determined by the loading of the system, involving a choice for the designer between the annualized cost of capital expenditure and the cost of energy losses. In practice between 5% and 10% of the energy sent out from the power station will be lost on the way to the consumer, the more distant the consumer, the higher the proportion lost.

Consumer Related Costs

This third category of costs covers such items as meter reading, billing and accounting, dealing with consumer public relations, complaints and queries, and is regarded as including the maintenance costs and an allowance for capital recovery (or provision for replacement) of the service connection and meter. The service connection is that part of the system that connects the consumer to the distribution lines or cables, and is intended to serve only an individual consumer. Where a connection fee is charged, this should be offset against the capital cost of the service connection, with provision, as previously, for eventual replacement of the asset.

The average cost of meter reading, billing, collection and accounting is likely to be between US$3 and $5 per month for an urban consumer, but will be substantially higher for rural consumers, as meter readers have to travel greater distances and as consumers are further apart from each other. While an urban meter reader will normally walk or use a bicycle, the reading of meters of rural consumers will probably require the use of a car, often on bad roads. An additional $2 to $4 per month would be required to cover other urban domestic consumer related costs, and these also would tend to increase with distance from the power station and with size of property.

These costs will, of course, be much lower in relation to self-contained rural systems where any meter reading will be undertaken by the plant operator, if there is one, or by a responsible member of the community. Except for capital recovery of the service connection, the resultant costs will be very small.

Overheads

Overheads made up of management and administration costs must also be recovered within the tariff rates. These are costs which cannot be directly apportioned to a specific activity, and the capital, operating and maintenance costs discussed above should be taken as including such overheads, which are recovered by adding a percentage to directly allocated labor and material costs.

Types of Rural Consumers

We should attempt to define just what we mean by a rural consumer, and decide whether all such consumers are similar, and hence uniformly affected by policy decisions, or whether there are sub-divisions. Two of the characteristics typical of rural consumers are low consumption density (i.e. the average kWh consumption per hectare) and this is often coupled with law consumer density (i.e. the number of consumers per hectare). Both of these have an important bearing on the cost of delivering electrical energy to the end user. In terms of costs it is the combination of consumption density and consumer density that is important, since it is more costly to supply 30 consumers per ha. with an average consumption of 50 kwh/consumer/month, than it is to supply three consumers per ha. with average consumption of 500 kwh/consumer/month, although the consumption density is the same in both cases.

Neither consumer density nor consumption density alone, or even together, will provide an adequate definition of rural consumers, although they may provide a convenient means of distinguishing between urban consumers on the one hand and adjacent peri-urban, as well as isolated individual consumers on the other. High housing densities coupled with low consumption densities are often encountered in rural villages, but may equally be encountered in those urban areas housing low income earners. The other factor that distinguishes the rural village from the low income urban area is its distance from an area of high load density and a power station, or the ability (in terms of potential load and the recovery of total costs) to justify its own power station.

It should be noted that the need to subsidize or cross-subsidize consumers does not necessarily determine whether or not they are rural. It has become accepted practice in many countries to have tariff structures that include so-called "life-line" rates, which provide for electricity supply to small urban consumers at rates that do not recover total cost, but rely on cross-subsidies from larger consumers to make up the shortfall.

We may, therefore, identify three types of non-urban consumer:

(a) Consumers living on large properties relatively close to, but typically beyond the municipal boundary of, an urban center which has an electricity supply. They are often classed as "peri-urban" and may be living on large properties because they are wealthy and want privacy, or because they are very poor and need the extra land to produce some or all of their food. The distinction is important in the context of RE, as the wealthy consumer should reasonably expect to meet the full cost of extending the electrical distribution system to his property, and to be charged an economic tariff, whereas the poor consumer probably would not be able to cover the capital costs of an electricity connection, and may also be unable to pay for electricity used if this is charged at the full cost of supplying him.

There may, of course, be peri-urban consumers living on small properties, but these would normally be found in groups, effectively constituting rural villages and falling into the next category.

(b) Consumers living in rural villages, which are either too far from the nearest source of electricity to permit them jointly to cover the cost of extending the transmission and distribution system, or they are in a location where there is no source of electricity available and there is not enough load to make construction of a power system viable. Even if a high voltage line passes very close to such a village, the cost of a substation may be such that, in the economic sense, they are still too far from the power station.

The above definition of a rural village would apply equally to urban or peri-urban housing complexes with low per consumer consumption potential, but in deciding on the extent to which such villages should form part of an RE policy, account should be taken of available local government facilities.

In developing countries the inhabitants of such villages normally have a low per capita income and would use only minimal amounts of electricity. In Pacific island villages consumption will be of the order of 10 kWh per household per month (representing the use of 100 Watt of incandescent lighting for three hours per day).

(c) Completely isolated consumers, generally farmers, whose farming activities might provide substantial electricity consumption e.g. for water pumping, and who may, in fact, already have generating units or directly driven pumps and other machinery. The distance between consumers may vary between wide limits.

The distinction between the above rural consumer categories is not precise, e.g. it may not be easy to decide how large a smallholding would have to be to shift a consumer from category a. to c., or how close to an urban center a village would have to be to be regarded as part of an urban complex, but the classification may be useful in policy formulation, and would indicate those costs which a study should seek to identify.

Rural consumers do not necessarily all have a low potential consumption of electricity. Mining companies, factories that process raw materials, resort hotels, large farms, and the like may be found in rural areas, often so far from a power source that they are obliged to generate their own electricity, and may thereby be very useful as a means of providing electricity to others living in the vicinity. There have also been repeated claims both in developed and developing countries that rural electrification (invariably requiring subsidies) will aid the decentralization of industrial development and reverse the drift of the population to urban centers. To date the author has not yet encountered a report that is able to provide acceptable evidence of such consequences of RE. In most industries electricity costs account for less than 5% of total costs, and even if electricity were provided free, such a small cost ingredient is unlikely to determine the siting of an industry.

For the purposes of this discussion on the requirements for formulating an RE policy, we are concerned with those potential rural consumers of electricity who will be primarily domestic and small business enterprises, including small farmers with limited, often mainly domestic, potential electricity use. Such farming, commercial or industrial use of electricity which is predominantly non- domestic is excluded, as it does not, in the opinion of the author, justify subsidized electricity supply, and an element of subsidy is an inevitable ingredient in an RE policy. Even water pumping, for village or irrigation use, which is frequently quoted as the justification for an otherwise non-viable IRE scheme, can often be provided at lower cost and with improved reliability, by means of diesel engine driven pumps", and does not in itself justify subsidy.

Rural Electrification Options

If we assume that a rural village is to receive a supply of electricity there are usually several options available to provide this, but unfortunately a simple comparison between these in order to select the least costly is usually not possible. The first reason is that the facilities and services that each option can provide will usually differ, the second is that there are typically neither adequate nor reliable cost data available, neither to assess the true cost of the various alternatives, nor the value of the additional benefits of one when compared with another.

The basic options are: connection to the public utility's or the electricity authority's grid; auto-generation; and PV systems. These will be discussed in this section.

(a) If the village is within reasonable distance of an existing transmission network, the potential consumers would have the benefit of a continuous supply of electricity with sufficient capacity to provide for the connection of such appliances or plant as they may wish to use and can afford to buy and operate. It is probable that the initial capital cost, both in total and per consumer, can be estimated with reasonable accuracy. This may be why a majority of RE projects is based on this option. Of course, if the village is too far, either physically or economically, from a network, or even on a more or less remote island, this is not a realistic option.

The additional costs involved in supplying rural as against urban consumers are not, however, limited to the additional capital costs. As discussed earlier, not only are there additional maintenance costs associated with the extra power lines, but all such costs are likely to be higher than they would be in the urban area. Similarly, consumer costs such as meter reading, connections and disconnections and maintenance of the service connection, are more costly because of the increased distance involved. These cost differences frequently are not identified in the utility's accounts, since they will disappear in the averaging process. The additional costs may not be significant if the proportion of rural consumers is small, but they will increase in importance if a programme of RE is initiated, or if, for any other reason such as a desire to total electricity sales, rural consumers grow at a faster rate than urban consumers.

The additional line losses involved in supplying the rural consumers are more readily estimated, but equally unlikely to be isolated and provided for in the costing.

(b) The next option, and in regard to isolated villages traditionally the major one, is the provision of a self-contained generator and distribution system. If this operates continuously, its benefits are comparable to those of a connection to a network. More usually, however, there is inadequate justification for continuous operation, and the generator may be run only some hours per day, typically for three or four hours starting at sunset, to provide for lighting only. Electric refrigerators used under these conditions will not provide enough cooling for long-term food storage. The loss of benefits when compared with continuous operation is difficult to evaluate, particularly in relation to the additional costs that this would incur. The assessment of both initial costs and recurrent expenditure is, in fact, extremely difficult, even where there are similar installations already in existence.

As already indicated, such installations are frequently installed by government departments that have no incentive or interest in recording true costs, which have to be traced to numerous budgetary heads, if they can be identified at all. If the installation is to be on an outer island, both installation and maintenance costs may be materially affected by the frequency with which the island is accessible from a base, coupled with the quality and reliability of the operator of the plant.

There are literally thousands, perhaps tens of thousands of diesel driven generating units, ranging in size from a few kW to several hundreds of kW, lying abandoned, often unrepairable, in RE projects all over the world. They represent an investment of many millions of dollars, and have often been in use for only a few hundred hours. They may have been replaced by new machines, or the total investment in plant, wiring and distribution may be unused and a complete loss. The risk of such losses in any particular project is impossible to assess with any degree of accuracy, but it increases with the remoteness of the site, and should be kept in mind when assessing the available alternatives.

(c) The third option, and the one which, in the author's opinion, offers the greatest promise for RE, is the provision of PV installations in individual houses. Again, the benefits are not comparable to those available with either of the above options, since the output normally available is suitable only for a limited amount of lighting, coupled with the use of a radio. The output of the solar panel, and hence the subsequent availability of lighting, is also affected by the amount of sunlight available. On the other hand, running costs should be very low; the wiring of the building does not require the skills and standards essential for 110 or 220 Volt supply, since a low voltage (12 or 24 Volt D.C.) is used, and if a unit fails to function, only one household is usually affected.

A PV installation may even be viable for small urban consumers, or involve a lesser subsidy than connection to the distribution system, where such a consumer uses only a few kWh per month. Higher initial costs would almost certainly be more than offset by the low operating and consumer costs.

Assuming that a decision has been made to include a rural village in an RE programme, the choice of option (to the extent that option a. is a realistic one) should then be based on the lowest cost that will provide the standard of service that has been selected as appropriate. The selection of standards of service may well require a government decision at Cabinet-level, and it may be desirable to provide for different standards of service according to location or consumer preference in the light of contributions required from them. This aspect should, therefore, form part of the recommendations for a coherent RE policy. The least cost could, of course, also be used as a means of selecting among a number of villages when a choice must be made. In order that both initial and recurrent costs are taken into account when comparing alternatives, a least cost determination will involve a discounted cash flow (DCF) analysis, which presupposes that a determination of realistic capital and operating costs (as far as this is feasible) has been made.

Transmission and distribution lines and equipment are normally assumed to have a 25 year life, compared with 10 to 15 years for PV units (3 to 5 years for batteries, whose replacement is regarded as an operating cost) and perhaps 8 to 10 years for diesel generators (although, if properly maintained and run, they may give 15 years service, particularly if not run continuously). Using a spreadsheet a DCF analysis is very simple, and sensitivity to various discount rates and generator lives can be tested. Provision should be made for the unexpired life of those assets whose life span does not correspond with the discounting period selected, by showing a positive cash flow equal to the unexpired value at the end of the final year. PEDP is also developing a Lotus spreadsheet based model to compare PV with other options.

The high cost of operating small diesel generator sets in rural villages is not usually realized. A village with 20 electricity consuming households and two community buildings is envisaged, with the generator run for five hours daily. Two of the households are assumed to have refrigerators which, as indicated earlier will not be very satisfactory under these conditions, but would be even less useful if the generator is run for only three hours daily. If the analysis is used as a template the input assumptions can be varied as desired. Only the two households with refrigerators would benefit from longer operating hours, but the generators would not operate satisfactorily at those times when the two refrigerators are the only load. The household kWh consumption on lighting could be substantially reduced by using fluorescent lighting, but because of the predominance of fixed costs, the savings would be limited, and may not offset the high cost of fluorescent fittings/lamps.

The example also makes a very basic comparison with a PV system in which the two owners of refrigerators either change to DC refrigerators operated in conjunction with a larger number of panels and batteries, or to kerosene refrigerators. In all cases lighting is assumed to be from solar panels. In this case also, by changing the input variables, it is possible to adapt the template to a particular set of circumstances.

Subsidies

The fact that the formulation of an RE policy is required is tantamount to accepting that an increase in the number of rural electricity consumers is possible only by providing subsidies, and probably an admission that an unknown number of rural consumers are already being subsidized. Since this is such a fundamental ingredient of RE policy, various aspects of subsidies will now be considered. To begin with we will see what additional costs, and hence what subsidies, are involved in connecting rural consumers to an existing network or grid.

The electricity tariff is intended to recover, in respect of each class of consumer (e.g. domestic, commercial, industrial) the three cost ingredients which were discussed above. As long as only kWh consumption is measured, there is a severe limitation on the accuracy with which these costs can be recovered. If there is only a flat kWh rate, only the overall average of all costs can be recovered, which results in cross-subsidies within the consumer class and possibly between classes. More accurate cost recovery is possible by combining the kWh charge with a fixed charge, which may be the same for all consumers in the class, or preferably, is based on a maximum demand to which their supply is restricted (e.g. by means of a load limiter or circuit breaker).

The fixed costs, whether recovered in a kWh charge or a separate fixed charge, will include a provision for the recovery of those transmission and distribution capital costs not paid by the consumer (e.g. in the form of a connection fee), plus a provision for the replacement of those assets funded by the consumer. The costs to be recovered will be average costs, at best the average for the consumer class. Even among urban consumers there will be substantial variation in these costs. Some of this variation is outside of the control of the consumer (e.g. costs depend on the location of the nearest substation, pole or distribution box, which are selected by the utility). Other causes of cost variation are determined by the consumer's choice as to where he decides to live and on what size of property.

In addition to the average, utilities should determine from their records and calculations the range of connection costs, and ideally, should charge each consumer the amount by which his connection exceeds a certain minimum which allows for those cost variations which are outside of the consumer's control. In practice this is rarely done. Most utilities charge no connection fee, or raise a uniform charge for all consumers, possibly differentiating only between single phase and three phase, and overhead and underground connections. As long as there are only occasional connections with costs that exceed the established maximum, these can be absorbed without seriously affecting the average, but the more frequently this happens, the greater is the extent to which the connection costs of some consumers are being subsidized by others. As the network expands into peri-urban and rural areas an increasing proportion of connections equal and exceed the maximum of the original range and thus raise the average.

The utility must now either increase its rates so that existing consumers subsidize those new consumers whose high connection costs have raised the average, or it must surcharge the new consumers' rates, or must charge them a connection fee or an additional connection fee. Despite legislation in most countries that requires utilities to avoid cross-subsidization it is probable that, as long as it is a gradual process, most utilities would claim that it is too difficult to quantify the subsidy, and they would increase rates. Consumers have become accustomed to frequent rate increases resulting from asset revaluations and increases in fuel costs, interest rates, and the like, and would probably be left unaware of the increasing subsidy they are being asked to pay.

On the other hand, if there is to be a declared policy of RE with the connection of hundreds or thousands of additional rural consumers at ever increasing distances from the central network, it is no longer possible to absorb the additional capital costs (perhaps not even the extra operating costs). The determination of the level of subsidy resulting from the difference between the average cost recovery provided for in the tariff and the actual costs in each case then becomes unavoidable. This difference will have to be recovered in the form of a capital contribution from the consumer, or from the government or from both.

It is important to note, however, that even if the total increase in capital cost is paid by a third party, the utility still incurs additional costs (as noted earlier) due to extra operating costs and increased contributions to the replacement fund, since these will exceed the provision made for the recovery of such costs in the tariff for urban consumers. These must be covered by a subsidy from existing consumers or from the government, or require a surcharge on the bills of rural consumers.

As we have noted earlier, these are not the only cost differences between urban and rural consumers, although they are the least difficult to quantify. Because of additional distance involved (possibly coupled with lower housing density) consumer costs may increase substantially, and if, as is probable, consumption levels are low, any subsidy already incurred in supplying small urban consumers is amplified in the case of rural consumers.

Looking now at the other options, self-contained generators and PVs, there is no difficulty in identifying the relevant cost items, but there is indeed (as already discussed) a problem in arriving at a reasonably accurate assessment of such costs. This will involve a detailed study of available historical records, probably coupled with a fair amount of guessing.

In the presence of so much uncertainty it would be foolhardy to embark on a major RE programme unless, and until, most of these uncertainties have been resolved. It would be prudent initially to undertake only a few closely monitored installations, and to monitor all existing installations with equal care. Unless there are fully reliable existing records, a minimum of two complete years of monitoring of existing and new installations would be required (even longer if there are no existing ones) before there can be sufficient confidence in the results to permit their use in projecting costs for a larger programme.

The following monitoring programme is suggested:

(a) Obtain comprehensive details of installation costs, including the in store cost of all materials used; hours worked and hourly costs of labor provided (including provisions for holiday and leave pay and all allowances), with working and travelling/waiting time recorded separately; travelling expenses; living-out allowances; cost of transport of materials; time spent and cost of direct supervision, also detailing travelling time and cost. Allow for oncosts on both labor and material costs (an initial estimate might be 15% on materials and 25% on labor, but labor oncost, in particular, is often much higher).

(b) Every generating site should be equipped with a logbook. At about the same hour of each day the operator, or person responsible for the operation of the engine should record the following and, where applicable, calculate in respect of the previous 24 hours:

(i) The reading of the kWh meter and the kWh generated;

(ii) The reading of the hourmeter, and the number of hours operated;

(iii) The amount of lubricating oil added;

(iv) The amount of fuel added to the day tank;

(v) If the generator cannot operate or has to be stopped, the cause and period without normal service should be recorded;

(vi) Details of any maintenance undertaken, and time spent.

(vii) At the end of each month, the daily consumption of lubricating oil and fuel should be totalled to obtain the total for the month. Average fuel consumption per kWh for the month should be calculated and compared with the value for previous months.

(c) Electricity meters should be read monthly, more or less on the same day of each month. A record should be kept of the energy in kWh used by each consumer, the amount charged for this and when payment has been received.

(d) If any service is requested from the center responsible for servicing the installation, a record should be kept of the date the service is requested, the date when the service is provided, the number of men that carried out the service, the time spent on the service, any materials used (with their cost, if available), time spent by service personnel in travelling/waiting, and the amount (if any) charged for the service.

(e) The records should be verified (as far as this is possible in retrospect) in the course of any subsequent service or inspection visit. A local government administrative officer, if available, should be asked to verify, on a regular basis, the records maintained. Records should be submitted monthly to an office in charge of RE projects.

(f) The returns should be examined on receipt and compared with previous returns with a view to correcting possible errors as soon as possible. Returns from various centers should be analyzed and with each other to establish patterns of consumption, cost, fuel efficiency, reliability, etc.

Subsidies - The Danger

In a society in which the decision as to what is or is not good for the citizen is not made by government, the citizen is more or less free to choose how to spend his income. A system of prices is used to indicate to citizens the cost and scarcity of the resources used to provide the goods or services on offer. If this relationship is distorted with regard to some goods and services, the consumer does not receive the correct information and there may be wastage of scarce resources through inefficient or unnecessary use. The potential for wastage in electricity supply tends to be higher than in most goods and services, because its production and distribution is very capital intensive, and in most Pacific island countries it depends on imported diesel fuel. In developing countries both capital and foreign exchange are invariably in short supply.

If RE consumers do not contribute towards the capital expenditure of connecting them, or if the contribution is inadequate, it is possible that not enough thought is given to the matter by potential consumers and that connections requested are not subsequently used or are under utilized. At the same time, other citizens who may have a greater need, cannot be connected for lack of funds. If the charge made for the use of electricity does not reflect the cost of providing it, consumers are encouraged to use it wastefully. This wastage is more typical of medium than of small consumers, and the effect frequently is that there is further subsidy of medium consumers by small ones, particularly if there is auto-generation and no metering.

As far as those who provide the subsidy are concerned, failure to make an accurate assessment of costs, or to recognize the presence of additional costs directly related to RE, may cause actual subsidies to be much higher than those budgeted for. This is often exacerbated by lower than projected revenue and utilization of assets, without any possibility of a corresponding reduction in fixed costs.

Subsidies - Who Pays?

In any discussion on RE policy there is a tendency to overlook the existence or creation of cross-subsidies, and to assume that subsidies, if required, would be met by government. In regard to subsidies resulting from an RE policy the government's concern should be to know:

(a) Whether subsidies are unavoidable;

(b) The extent of such subsidies both per consumer and in total;

(c) Whether these are "once only", i.e. capital subsidies or whether there are also recurrent ones; and

(d) How to limit both capital and recurrent subsidies to ensure that the maximum number of citizens will benefit and that available funds are not exceeded.

Where rural consumers are to be connected to an existing network or grid, the alternative (if not the main) potential source of RE subsidies are existing, usually urban, consumers who may or may not be aware of the fact that some of their electricity charges are used to subsidize other consumers. As we have seen, this form of subsidy is probably most common in respect of recurrent costs where the additional costs incurred in respect of rural consumers are not easily identified, and cost recovery is based on overall averages. Increases in connection costs can be hidden when there are only occasional connections of rural consumers involved, but this is no longer possible if there is to be a policy of RE that may result in hundreds or thousands of rural connections.

There can be no justification for attempting to hide from government the extent of the subsidy required either from them or from other consumers, and in the author's opinion, there is also no justification for hiding this from both the recipients and benefactors among the consumers, if only to keep a record of the extent of the subsidy and to prevent it from getting out of hand. As far as consumers are concerned, it is usually argued that as long as only a small proportion of the population has access to electrical services, these should be willing to make some contribution towards the cost of providing the same service to less fortunate citizens.

On the other hand, tariff structures in many countries are such that all small consumers are subsidized to a greater or lesser extent by the larger ones. Rural consumers then benefit from a double subsidy caused first by the extra costs incurred by the fact that they are rural, together with the subsidy that most of them will receive because of their size. In practice, this will apply to most rural consumers obtaining an electricity supply under an RE policy.

An equitable means of making the extent of cross-subsidization apparent and restricting it would be to set up an RE Support Fund into which a certain proportion of annual electricity sales turnover is paid each year, and against which that proportion of all costs that can be identified as relating only to rural consumers is charged. This will require some detailed analysis of costs, but as most of these are repeated at regular intervals, this should not present major problems nor involve substantial accounting costs. An RE support Fund as such, however, would not avoid any increase in the total cross-subsidy which small consumers may receive from other consumers in consequence of a "life-line rate" in the tariff structure.

If such a policy is adopted government may be able to restrict its commitment to the payment of capital subsidies, and to avoid becoming involved in the subsidy of recurrent RE costs. The adoption of the tariff proposals made later in this paper which will minimize the extent of the recurrent subsidy to small consumers, would be of assistance. This would also restrict subsidies provided to urban consumers by virtue of the tariff structure. Since there is likely to be a limit to the total subsidy that can be extracted from the larger consumers, it should not be the object of an RE policy to provide electrical service at less than the amount that potential consumers were paying for other forms of energy, since the most likely effect of such a saving would be to prevent the wider enjoyment of the same benefits.

This still leaves unanswered the question as to how to provide funds for the initial capital expenditure involved in an RE project:

(a) To construct additional transmission and distribution lines and substations;

(b) To reinforce the system, as required, to carry the additional load by rural consumers;

(c) To supply and connect the individual properties; and

(d) To provide the electrical installation in the buildings that are to be connected.

A substantial proportion of these funds would probably have to be made available by government, either from its own resources or through loans, as part of an RE policy. Here too, it is essential to make the most use of available funds by setting limits to expenditure and by requiring some participation by the potential consumers. Some suggestions are made in the next section. A most important aspect, however, remains the accurate determination of the costs that will be incurred, so that there is a clear realization of the commitment and of the number of households that will actually benefit.

The situation in regard to self-contained generating and distributing systems is, of course, rather different, since there are no existing consumers who can be called on to carry some, or all, of the subsidy on recurrent expenditure. While the same principles can be applied in regard to the initial capital expenditure, an accurate study of likely operating costs is required to decide whether, and to what extent, consumers can be required to cover all recurrent costs, including those related to the eventual replacement of the plant and equipment. It is probable that some subsidy will be required, and government would have to make adequate provision for this, or risk the possibility of the total expenditure being wasted.

It should be noted that, whereas in a network with properly designed tariffs the effective subsidy applied to small consumers from larger ones decreases as the small consumers' consumption increases, the subsidy available to consumers in isolated generating systems to cover recurrent expenditure is less likely to diminish. This is due to the restriction on possible electricity use because of poverty or limited plant operating hours, and there may be increasing subsidy with increasing consumption. The reason is that the proportion of fixed costs in a large interconnected network is high, while a larger proportion of total costs in a self contained system, in the form of fuel and maintenance costs, is variable.

The financing of the wiring of rural buildings regularly poses problems of RE policy, particularly in remote island villages. If the consumer is required to pay the cost of wiring, however basic, in addition to a financial participation in the capital cost of an electricity connection, this will materially reduce the number able to participate. It may therefore be necessary to include the wiring cost in the total amount towards which a subsidy is available, but this may then raise the amount of subsidy required to unrealistic levels. This is a further argument in favor of PV systems in which basic wiring is included, but where auto-generation is unavoidable, an additional subsidy may have to be provided for isolated (adequately defined) rural consumers.

Finally, a capital subsidy would probably also be required for rural use of PV systems, and it is reasonable that consumers be treated in similar manner to those receiving mains supply. There is, however, the probability that no subsidy will be required for current expenditure, as this should be within the financial capacity of the consumer. To ensure that funds are available for maintenance as well as battery replacement, and for the eventual replacement of the PV system, the consumer should be required to make a monthly contribution towards a fund set up for this purpose.

Subsidies - How Much?

Before indicating how limits might be set on the subsidies that may be incurred in various ways in the implementation of a RE policy, it may be useful to review the information required for this purpose.

(a) Capital Costs - To begin with, there is the capital subsidy, requiring the accurate costing of the works to be undertaken, be they the reinforcement and extension of an existing network, or the construction of a self-contained generating facility with its distribution system, or the installation of PV systems. In all cases costs should be fully inclusive, covering transport, housing of personnel, travel, supervision, subsistence, waiting time, and all other overheads. Such costs would generally be calculated per village, or per isolated consumer, and should then be distributed over the number of consumers that are certain to be connected (and remain connected), to arrive at a cost per consumer.

Where remote villages are concerned, the number of consumers is particularly important, even for PV systems, as there are fixed costs that will be shared among all of the households concerned. To the relevant proportion of these shared costs should be added those costs incurred in respect of each consumer to arrive at the total cost for every consumer to be connected. In practice the individual consumer costs may be sufficiently similar to permit the use of an average figure, provided this does not result in further subsidies or cross-subsidies.

In the author's view, an equitable basis of subsidy should make available a maximum amount per consumer, (rather than a percentage of the total cost of connecting any particular consumer, or the cost of a length of line or service connection). This should be subject to a requirement that every consumer should contribute, as a minimum, a certain percentage of the total cost involved in the connection (and wiring, where appropriate) of his premises.

This is to say that if the government has decided to make available a maximum subsidy of $400 per consumer with a minimum consumer participation of 25%, the consumer would have to pay $125 if the connection cost is $500; $200 if the cost is $600 and $80 if the cost is $320.

Not only will this limit the total potential subsidy that may be required from the government to provide service to a given number of households, but an adequate participation of each consumer will ensure that he is financially interested in the success of the policy. At the same time, this approach should result in preference being given to the more viable projects, and if it favors the wealthier communities, these are also more likely to continue to support the scheme once it is in operation.

To ensure that only consumers who cannot afford to pay the full cost of the service are subsidized, it is proposed that any consumer contributing less than a substantial percentage of total cost (e.g. 80% or 90%) should receive a restricted supply, i.e. a circuit breaker/load limiter is installed that will permit only the use of lights and a radio. This would typically be a 1 Amp limiter and it could be specified that the restriction is for five years, but that the consumer may at any time have the rating increased on refunding the subsidy, reduced pro rata if there has been more than one year of use with restricted load. The restriction would also ensure that a consumer does not consume beyond his ability to pay, and can (with reservations) be used for small consumers in lieu of metering.

The same subsidy, and on the same conditions, could be provided for PV installations, but in this case there would, of course, always be a restriction on use. If the choice of mains or PV is left to the consumer, it is essential that the consumer is made fully aware of the advantages and disadvantages of PV. This may not be an easy matter initially, but will be facilitated as more PV installations are in use, and potential consumers can seek advice from existing ones.

One question that always arises where the public contributes towards the capital cost of public utility projects is that of ownership. Where a consumer has contributed towards the cost of a distribution line, "his" part of the property is difficult to identify, but where a consumer pays for a service connection, or even a PV installation, identification, and hence questions of legal ownership, become more difficult. Public utilities usually have suitably worded clauses in their service agreements giving them ownership of all assets, even if paid for by the consumer; and in consumer credit orientated societies the repossession of goods for failure to pay installments is an accepted fact of life. The reaction of a Pacific islander to the removal (because of non-payment of monthly contributions) of a PV panel towards which he paid $100 or more is clearly something that must be considered, and he should be made aware of the possibility that this might happen.

(b) <u>Recurrent Costs</u> - The following types of recurrent costs and subsidies may be involved in the supply of rural consumers:

(i) In respect of consumers connected to an existing network, operating costs and provision for capital replacement of extra transmission and distribution lines, line losses on such lines, and additional consumer costs.

(ii) Also in respect of consumers connected to an existing network, the effective subsidy (if any) applicable to all consumers in the consumption range into which the new consumers are likely to fall, in consequence of the level of their consumption.

(iii) In respect of consumers connected to an isolated system, total running costs of the system, including fuel, operating and maintenance costs and consumer costs, and provision for the replacement of assets.

(iv) In respect of consumers to be provided with PV systems, maintenance costs including battery replacements, and provision for the eventual replacement of the system.

As mentioned earlier, accurate determination of these costs may be difficult, but is important. The following proposals are made with a view to limiting the subsidy that may be required in covering recurrent costs:

Consumers Connected to an Existing Network:

(a) Every consumer should be required to pay a monthly fixed charge in addition to the energy charge. This should apply to all consumers, urban and rural, but the fixed charge for rural consumers could be (and probably should be) higher to reflect higher consumer costs. The fixed charge should be related to the rating of the connection, but should not be less than a predetermined minimum.

(b) Every consumer and every service connection should be subject to a minimum charge, whether electricity is consumed or not. This amount should be such that the total recovery from the smallest consumers using lighting only is about the least that they would have to spend on lighting if a supply of electricity were not available. This could also be varied as between urban and rural consumers. The annualized fixed cost of connecting a consumer is likely always to be higher than the minimum so established, so that an element of subsidy will always remain.

(c) The number of kWh per month available to any consumer in the form of a reduced rate (i.e. subsidized) first block should be limited to between 10 and 25, which is intended to cover the basic use of lighting and a radio. 15 kWh per month allows the use of three 40 Watt incandescent lamps for four hours daily - or several times as much light output if fluorescent lamps are used, and is, therefore, generous level of subsidized supply.

(d) To avoid claim of discrimination, a common tariff structure should be applied to all consumers of the same class or category. The effect of this would be that all consumers would benefit from the subsidy, but large consumers would have a higher fixed charge and the number of subsidized kWh will be a negligible proportion of their total consumption. To small consumers, on the other hand, the only penalty of exceeding the subsidized kWh will be a gradual rise in the average cost per kWh,

and if their consumption were double the subsidized level, they would still be paying only the average of the subsidized and full rates.

(e) Consumers using electricity only for lighting and a radio and having their supply restricted by means of a 1 Amp or 0.5 Amp load limiter could be supplied unmetered (or with the meter used only for occasional verification) at a fixed monthly charge. A fixed charge simplifies budgeting by the consumer, can be made payable in advance (thereby limiting bad debts) and avoids the need for meter reading, (thereby further reducing consumer costs).

Consumers Connected to an Isolated System

(a) The principles set out in respect of consumers connected to an existing network have some application, but the tendency would be for monthly fixed rate tariffs.

(b) Monthly fixed rates should be based on the rating of a load limiter to avoid the possibility of those able to afford appliances being subsidized by those that cannot.

(c) Where there is a 24-hour service this would require the employment of at least one full-time plant operator, who could also read meters. In such places, therefore, meters should be installed for all consumers, but possibly excluding those restricted with 1 Amp or 0.5 Amp load limiters.

(d) Consumers connected to government owned and operated rural generators at schools, hospitals, clinics and the like should be restricted with load limiters, metered and charged for electricity consumed at realistic rates. All too often one hears about such consumers receiving free electricity and using this (with a real cost which is probably in excess of $1 per kWh) for cooking or even water heating. It does not take long before it becomes accepted that electricity is cheap and should be free for everyone.

(e) If there is only restricted service it is possible to do without metering but not without load limiters (see note (b) above). There should be a kWh meter on the generator as well as an hour meter, and these should be read by the operator as a check on the mechanical performance of the plant and its utilization, as well as on the proper use of fuel.

Consumers Provided with PV Systems

(a) There will be no charge for electricity consumed, but consumers should be required to make monthly payments into a replacement fund, the amounts being such as to cover the cost of replacing the PV unit at the end of its expected life, as well as the cost of replacing the battery every three to five years and any other maintenance. It is, of course, rather more difficult to enforce such payments, since it is not as easy to remove a PV installation for non-payment as it is to disconnect a consumer receiving supply from mains. On the other hand, removal of the PV unit represents a higher recovery of capital costs than is possible in other cases.

(b) If, as suggested earlier, the supply and installation of PV units is left to private enterprise under government supervision, it should be possible to shift to the supplier the risk of dealing with premature failures by making a suitable agreement with him, ideally even leaving him to collect monthly contributions from the consumer, or to have them collected on his behalf by a local agency.

The Institutional Framework

It will be apparent from the foregoing discussion that a methodical programme of RE cannot be an ad hoc affair, to be tackled in their spare time by a selection of social workers, local government officials and university students, and accordingly the planners' RE recommendations should include proposals for institutional arrangements.

We may identify the following three stages in the implementation of an RE programme:

(a) The planning and selection stage, in which applications from potential rural electricity consumers are first processed. There will be consultation with the applicant(s) to ascertain whether there is a genuine demand for electrical service, whether the required financial contribution is available, and which of the available options are appropriate, taking into account the applicants' expectations and requirements. This may involve discussions with project agencies, depending on the options available, and will require a site visit either by the planner (in this case the person responsible for this stage) or the project engineer, at some point before there is final commitment to a project. The contribution from the applicants will have to be collected and there must be assurance that all funds for the completion of the project are available and committed.

(b) The project stage would cover the actual construction, be it the extension of the electricity authority's network, the erection of a local power station and distribution network, or the supply and installation of PV units. The executing agency may be a government department, the electricity authority or private enterprise, but there should be adequate consultation with the planner, and it would probably be best if ultimate responsibility is retained at this stage by the planner or agency that handled the first stage.

(c) The operating and supervising stage commences with the completion of the project. At this point responsibility is handed over from the planner to an agency that will have responsibility for the continuing and efficient operation of the various projects that have been completed. There will be a need to ensure that the plant is serviced, meters are read, contributions are collected, and that records are maintained, and that such advice and training as may be required by members of the community to whom these various tasks are delegated is available.

The failure to monitor completed projects to ensure proper operation, maintenance, keeping of records, charging, and collection of moneys due is highlighted in several reports as a major weakness of completed RE projects. If the project is supplied by the electricity authority's network most of these tasks will be handled by them, but statistical and accounting records should still be maintained in all cases, particularly in regard to subsidies.

In some Pacific island countries there have been RE proposals to provide electricity to thousands of rural consumers with expenditure running into millions of dollars. The need for (and cost of) adequate institutional support for such large schemes should not be underestimated.

Conclusion

An attempt has been made in this paper to study in detail the problems that face a planner who is required to provide recommendations for a national RE policy.

On the available evidence, there is considerable doubt that RE is an important priority for most rural Pacific islanders, and the first task of the planner must, therefore, be to verify, as far as he is able to do so, that there is a substantial body of rural opinion that favors RE over other services that are lacking or inadequate. If he finds that rural citizens attach a lower priority rating to RE than to other services, he will have the (possibly more difficult) task of persuading the government that this is so.

If there is, indeed, a demand for electrical service in rural areas, then the first objective must be to collect accurate costs on which projections for the cost of an RE programme can be based. As detailed above, this is a difficult task, but it would be unwise to attempt any large scale projections until reliable data is to hand, even if this takes time to collect (the author suggests that this may need two years or more where isolated communities are concerned).

It may be possible to start by analyzing costs of supplying peri-urban and rural consumers that could be supplied from existing urban undertakings, and it is possible that this is where a priority for electrical service would first become apparent. This information will not, however, allow for the formulation of a national RE program, and politically it may be seen as further concentrating the benefits of electrical service in one or two regions or islands.

The detailed analysis of existing distribution costs of urban electricity supply and the determination of additional costs incurred in extending this to rural areas may require specialist outside assistance, but will provide some data on which policy recommendations on the extension of the existing distribution network can be based. It should also be possible at this stage to compare projected costs with those applicable to PV systems, to look into the question of wiring rules and savings that can be made by lower distribution costs, and to get some idea of the subsidy per consumer and contribution from consumers that would be appropriate.

This initial data will enable the planner to give the government some indication of the subsidies that are likely to be involved, and to make recommendations as to how, to what extent, and at what rate, they could be or would need to be covered. Both capital and operating subsidies would, of course, be considered. The data would be supplemented with additional data collected from experimental isolated rural systems from time to time, until a reliable data base has been established on which a national RE programme can be based. The author suggests that such a programme should include suitable recommendations for an institutional framework, and if some, or all, of the programme proceeds, the available data should be updated from the records furnished by operating projects.

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Load Limiters

There are few countries in the Pacific region that use load limiters, and as they are very valuable as an adjunct to, or a replacement for, kWh meters, particularly in relation to small electricity consumers, their rationale and use is explained here.

In essence the load limiter is simply an automatic circuit breaker as will be found on the distribution board in most modern homes, i.e. a device that will interrupt the electricity supply if the current exceeds a predetermined level, known as the rating of the circuit breaker. The only difference between a load limiter and circuit breaker lies in the degree of accuracy in the response to an excess current.

Circuit breakers cannot respond to an excess current instantaneously, but the speed of the response is inversely related to the extent by which the current exceeds the circuit breaker rating. At high (fault) currents the response is very fast to avoid damage to the wiring, but near the rated load of the circuit breaker the response time becomes infinite, i.e. the circuit breaker will not trip. Circuit breaker manufacturers will normally guarantee that the breaker will not trip at the rated load, but will trip within a few seconds with a 25% overload. Some delay in the operation of the circuit breaker near its rated load is essential to avoid spurious tripping when an incandescent lighting load corresponding to the rating of the breaker is connected, or when a motor is started.

The response mechanism of the breaker may be purely magnetic, or it may be both magnetic and thermal. In the author's experience, breakers with both magnetic and thermal devices tend to be less accurate than purely magnetic ones in hot climates, particularly if placed in meter boxes exposed to the sun.

The degree of inaccuracy in the response of a circuit breaker is not serious when used as a protective device, but if it is to be used as a metering device the cumulative effect of many hundreds or thousands of consumers exceeding by perhaps 10% or 15% the load for which they are paying can lead to substantial under recovery of revenue. In practice the minimum overcurrent that will cause tripping within a few seconds but will permit connection to an incandescent lighting load of the rated capacity is 10%. Circuit breaker manufacturers will normally supply their standard product as load limiters by selecting those breakers of their production that have the response accuracy specified by the customer. The extra cost of load limiters, in effect, is a payment for the additional expense incurred in testing and selecting.

Where there are small numbers of consumers involved, there is no reason why regular circuit breakers should not be used as load limiters. It is always the consumer who will benefit from such a decision, and if all consumers in a village have load limiters, they will all have an equal chance of benefiting. In the discussion on the components of the cost of electricity we distinguished between fixed and variable costs. While variable costs can be recovered by metering the kWh used by a consumer the equivalent metering device for the recovery of fixed costs is the maximum demand indicator. Not only is this an expensive meter, but consumers have difficulty in grasping the concept of maximum demand, and a preferred method of allocating fixed costs equitably between small and not so small domestic and commercial consumers have a fixed charge which is varied in line with the demand which the consumer will impose on the system. This method is widely employed, particularly in continental European countries.

Load limiters are by no means the only devices used to restrict a consumer to the level of load for which he is paying, but they are by far the least expensive and most readily available. Their only disadvantage lies in the fact that there is an interruption in the consumer's supply if he exceeds the contracted load by more than the tolerance of the breaker or load limiter, and he cannot reconnect himself until he has switched off some of the connected load. Some difficulty may be experienced in obtaining off-the-shelf supplies of 1 Amp and O.5 Amp circuit breakers, as these ratings are not normally employed in the protection of wiring circuits, but they should be readily available from the manufacturers.

Where the consumer is unlikely to use electricity continuously (e.g. where the generator is run only for some hours each day), or where there is adequate certainty of a pattern of consumption (e.g. where the rating is such that electricity can only be used for lighting and a radio), the kWh meter can be dispensed with, or used only for occasional verification. In that case the load limiter effectively becomes the metering device. Whenever a circuit breaker or load limiter is used for metering, on its own or with a kWh meter, it should be sealed with wire, lead seals and sealing pliers, or plastic seals) in the same way as the meter, so that the consumer cannot tamper with it.

A little story will illustrate the need for sealing as well as the use of load limiters. The Council of what was then Salisbury in S. Rhodesia, some 25 years ago, decided to offer a subsidized electricity supply to low income earners living within its boundaries. It was intended that the service should be used only for lighting and a radio, and to minimize costs and permit monthly payment of a fixed amount in advance, consumers' services were restricted with a 1 Amp load limiter unrestricted service at much higher economic rates was also available) . Many thousands of such connections were made. The load limiters were enclosed in metal cases which were sealed, and the seals were inspected from time to time. One day an irate consumer appeared at the offices of the Electricity Department: He had just had electricity connected to his house, and on the advice of some friends had paid the City Council's electrician an extra £5 so that he would by-pass the load limiter. But the electrician had clearly not done his job properly, since the moment he switched on his refrigerator the load limiter tripped. His friends had no such problem with their refrigerators and he wanted the matter put right or wanted his £5 back!

Electricity Tariffs in Pacific Countries

These data were obtained from country energy offices by PEDP in 1988.

Analyses undertaken by the author on behalf of PEDP in various Pacific Island countries (often with rather inadequate data) suggest that the average cost of supplying electricity in the region from diesel engine powered generators based on the current cost of assets, is between 18 and 30 US cents per kWh. Of the countries listed only Fiji and Papua New Guinea generate a substantial proportion of their electricity sales from hydroelectric sources.

Rates quoted are per kWh in early 1988 unless otherwise indicated.

COOK ISLANDS

Domestic Consumers:	0-120 kWh/month: NZ$0.20/kWh Above 120kWh/month NZ$0.25/kWh
Commercial consumers:	NZ$0.39
No minimum charge	

FEDERATED STATES OF MICRONESIA (1986)

POHNPEI

First 2000 kWh/month	US$0.03
Next 8000 kWh/month	US$0.08
All over 10,000 kWh/month	US$0.23

KOSRAE

All consumption	US$0.05

YAP

First 1000 kWh/month	US$0.09
All over 1000 kWh/month	US$0.12

TRUK

Domestic consumers:	
First 1000 kWh/month	US$0.06
All over 1000 kWh/month	US$0.09
Commercial consumers:	US$0.10

FIJI

Domestic consumers:	F$0.186 Minimum charge F$3.22/month
Commercial & Industrial:	F$0.196 Minimum charge F$6.52/month
Institutional	F$0.186 Private schools, churches, etc.
Minimum charge, Domestic:	F$3.72
Minimum charge, Commercial & Industrial:	F$7.84
Maximum Demand tariff	(available to Industrial & Commercial consumers with a maximum demand greater than 75kW):
Energy charge	F$0.126
Demand charge	F$16.2/kW/month Minimum charge F$1,215/month
High Voltage supply:	4% discount
Reactive power:	F$0.116/kVArh/month, minimum power factor: 0.85
Street lighting:	F$0.15

KIRIBATI

Domestic Consumers:	A$0.32
Commercial & Industrial	A$0.36

NIUE

Basic rate:	NZ$0.27
Minimum charge:	NZ$2.50/month

PALAU. (1986)

First 1000 kWh/month	US$0.09
All above 1000 kWh/month:	US$0.10

PAPUA NEW GUINEA

Domestic Supply:	
First 100 kWh/month	K0.10/kWh
Over 100 kWh/month	K0.14
Minimum Charge	K5.00/month
Commercial Supply:	
All kWh	K0.14/kWh
Minimum charge	K5.00/month
Industrial Tariff:	
All kWh	K0.08/KWh
Demand charge	K10/KW/month
Minimum charge	K2,000/month

SOLOMON ISLANDS

Domestic consumers:	SI$0.295
Government, Commercial & Industrial:	SI$0.325
Minimum charge:	SI$2.50/month

TONGA

All consumers:	T$0.2385 Minimum charge: T$2.86/month

TOKELAU

Flat rates:	
Atafu	NZ$4.00/month for lights; NS$0.50/month/power point
Fakaofo	NZ$4.00/month for lights; NZ$2.50/month/power point
Nukunono	NZ$5.00/month for lights; NZ$3.00/month/power point

TUVALU

First 100 kWh/month:	A$0.30
All over 100 KWh/month:	A$0.38

VILA

Small domestic consumers:		
First 60 kWh/month	14.28 Vatu	Consumers regularly exceeding
Next 60 kWh/month	23.80 Vatu	120 kWh/month are classed as
All over 120 kWh/month	35.70 Vatu	General Purpose
General Purpose consumers:		
Basic energy rate:	23.80 Vatu	
Off-peak rate: *	14.28 Vatu	2230 to 0630 hours; higher KVA charge
Demand charge:	357 Vatu/contracted KVA/month - minimum charge	
High Voltage consumers:		
Basic energy rate:	14.28 Vatu	
Off-peak rate: *	11.90 Vatu	2230 to 0630 hours; higher kVA charge
Demand charge:	476 Vatu/contracted kVA/month - minimum charge	

* Off-peak rates were discontinued in October, 1986.

Public lighting:	16.66 Vatu

LUGANVILLE

Low Voltage supply - lighting:	
First 50 kWh/month:	33.90 Vatu
Next 50 kWh/month:	30.51 Vatu
Next 900 kWh/month:	27.12 Vatu
All over 1000 kWh/month:	22.035 Vatu
Low Voltage supply - other appliances:	
First 50 kWh/month:	27.12 Vatu
Next 50 kWh/month:	20.34 Vatu
All over 100 kWh/month:	18.645 Vatu
Fixed charge:	576 - 1390 Vatu/month
High Voltage supply:	
First 50 kWh/month:	23.73 Vatu
Next 50 kWh/month:	18.645 Vatu
All over 100 kWh/month:	15.255 Vatu
Demand charge:	67.8 Vatu/kVA/month
Public lighting:	22.035 Vatu

All consumption:	**WS$0.28**
Minimum charge:	**WS$4.00/month**

RURAL ELECTRIFICATION POLICY GUIDELINES FOR THE PACIFIC ISLANDS

PEDP 1/

Summary

Policy for rural electrification in the Pacific Islands should provide for:

(a) An independent rural electrification authority that can share technical and physical resources with the urban electricity authority but has separate administration and funding. The authority should be formed in such a fashion that it can seek finance from aid agencies or international development banks with minimal interaction with other government agencies or departments.

(b) The same department that makes policy for rural electrification should make policy for urban electrification and should oversee both rural and urban authorities.

(c) The rural electrification authority should specialize in independent village scale or individual scale systems while the urban authority should specialize in multi village grid delivered power systems. The oversight authority should make the decision as to which authority has jurisdiction in a service area.

(d) Electrification for economic development should be tied to specific economic development projects. Subsidies for capitalization and plant operation during the early years should be made available based on the type of installation and the importance of electricity to profitability of the project. Tied intimately to these subsidies should be the requirement for minimizing power waste through energy conservation measures as directed by the oversight department.

(e) Electrification for social development should have no subsidy for operation and only a partial subsidy for installation.

(f) The authority, not the user, owns generation equipment and all wiring. Appliances are the responsibility of the user though they may be financed by the authority.

(g) All persons associated with administration, fee collection or system maintenance are full employees of the rural electrification authority. A village co-op may be set up for financing the electrification but should not provide collection, administration or technical services.

(h) Policy should state and the authority should enforce disciplinary measures against users that violate their agreement to pay periodic fees or in some way modify the system to its operational detriment.

1/ Report REG 88-6, July 1988

(i) **Community leaders, in the case of social development electrification, or project management, in the case of economic development projects, should be involved in all stages of system selection, design, financing and installation.**

(j) **The technology used for rural electrification should not be fixed but should vary according to the needs of the user and the characteristics of the site. Technology selection should emphasize recurring costs not initial cost. Different selection criteria should be used for economic development and social development electrification.**

Introduction

Rural electrification policy as developed in this paper is based on the assumption that a decision has been made by the government for rural electrification to proceed on a major scale and it has become necessary to define the organizational structure, operating mechanisms and technical guidelines for rural electrification.

Non-Technical Problems in Pacific Rural Electrification

The technical problems of rural electrification are generally well known but there are a number of non-technical problems which have not received much attention. Some of the more important are:

(a) The cost of rural electrification is unknown. In very few cases has the real cost of rural electrification projects been accurately recorded. As a result, it is very difficult to budget for rural electrification. Policy must be flexible enough to allow for actual costs that are significantly different from those projected initially.

(b) Political pressures are strong to electrify certain areas or in certain ways. The policy should create a system for electrification as independent of the political system as possible.

(c) Aid donors often work outside of stated national policy and may attempt to put pressure on recipients to accept certain projects or certain technologies for rural electrification whether appropriate or not. Government policy should require all projects which include energy production or significant energy use to be evaluated by a government energy agency before being approved.

(d) Agencies such as national development banks which, in effect, make major development decisions do not involve energy authorities in the decision making process. Policy should create links between rural development agencies and the rural electrification authority to ensure interaction.

(e) The cost of rural electrification cannot be controlled locally; it is too dependent on foreign technology and foreign currency fluctuations. Wherever practical, locally available fuels, materials and labor should be involved in rural electrification.

(f) **Once electricity subsidies are introduced, it is very difficult to eliminate them. Subsidies should be limited to initial capitalization or limited in term contractually at the time of inception. No subsidies should be instituted for operating and maintenance costs of systems installed for social development purposes.**

Defining Rural Electrification

Rural electrification in countries contained on one land mass is usually based on grid extensions from a relatively few large-scale generating plants. This means of rural electrification is not available to the Pacific islands except on a limited scale in the larger islands. Because of the nature of the rural districts in the Pacific, only village scale or individual scale systems will be practical for the great majority of rural installations.

Although urban based electricity authorities have successfully carried out grid extension type rural electrification in many countries, in most Pacific nations, urban type electricity authorities are not properly equipped, either administratively or technically, to deal with the large number of remote, small scale, power plants required by Pacific island rural electrification. Therefore, a separate organization specializing in stand-alone system rural electrification is recommended.

The policy evolved for rural electrification in a Pacific country must therefore deal with two intertwined but separate electrification authorities, the urban authority with its urban grid extensions to rural areas and the rural electrification authority with its stand-alone power plants.

A single government department should have both electrification authorities under its policy control. It is not practical, for example, to have a Public Works Department establish one rural electrification policy for outer islands and an Energy Department establish another electrification policy for main islands.

Determining the Mode of Electrification

In those countries having many villages which can be electrified either by stand-alone systems or by grid extensions, there must be a mechanism to determine which electricity authority should provide services. The determination should be made by the government department overseeing the two electricity authorities and should be based on a balanced consideration of several factors:

(a) Relative life cycle cost of grid extension vs. stand-alone generation: The cost of installing and operating the stand-alone system should be weighed against the installation and maintenance cost of extending the grid. Government subsidy will be involved in either task since it is almost never possible for the rural village itself to afford the investment necessary to initially bring electricity to the community. In addition, the source of money must be considered. Money may be readily available for grid extensions but not for stand-alone power plants or vice-versa.

(b) The impact of the addition of this village to both electricity supply agencies ability to provide service to existing customers: If the urban system is at the limit of its capacity, adding more load through grid extensions is not appropriate. If the rural electrification authority is having severe problems keeping its present inventory of power plants running, adding more to their system is not wise.

(c) The preference of the village involved: Though not binding, the preference of the village should always be sought and if their preference cannot be provided, a clear explanation of the reasons for government's decision.

(d) The load structure of the village: A large village with several commercial establishments or an industry likely to have significant electric load would usually be better served by a grid extension while for a small village with a small load which is mainly evening lighting a stand-alone plant is the better choice.

Development Concepts

Rural electrification is almost always a component of what is called rural development. Several definitions of development are in common use and the first consideration in creating a national rural electrification policy must be to define what the development goals are for the programme.

The most common definition of development is in the economic sense. The goal for economic development programmes is basically to change economic patterns from barter and communal subsistence production to a cash oriented economy.

Another valid definition of development is the systematic improvement of living conditions through advances in housing, sanitation, water supply and communications. This is often called social or quality of life development.

These two approaches to development philosophy are intertwined. Improving personal living conditions generally produces conditions favorable to economic development and economic development usually leads to the increased cash flow in a community being used for the improvement of living conditions. Programmes directed toward both modes of development may be operating simultaneously with some directed toward economic development and others directed toward living standards development.

Which development approach is used is dependent on the philosophy of development adopted by government and upon the relative likelihood of success of the two modes. Economic development requires the following elements of a money economy to be present at the development site:

(a) a production facility which can economically produce items for sale;

(b) sufficient willing, trained labor to operate and administer the facility;

(c) local banking institutions for ease of access to capital and money transactions;

(d) a stable, long term market for the goods produced which can absorb the quantity produced;

(e) adequate transport infrastructure to insure economic access to raw material supply and to markets; and

(f) the project must provide a profit to the community without continuing subsidy though it is often reasonable to subsidize initial capitalization.

If any of these factors are not present at a site, economic development does not occur.

Sites to be developed through standard of living improvements also must meet a set of criteria before success is possible:

(a) the improvement proposed must be desired by the recipients;

(b) the recipients must be willing and able to bear at least a significant portion of the recurring costs associated with the improvement project;

(c) adequate willing and trained labor must be available locally for operation and maintenance of project hardware, and

(d) adequate financial, administrative and technical support must be available. It if is not present within the community, it must be available from the outside.

Development through standard of living improvement can be expected to succeed only if all of these factors are present.

Basic Criteria For Rural Electrification

For national electrification to provide the maximum development benefits with a minimum of initial cost and upkeep expense, rural electrification policy needs to be designed in such a manner that:

(a) Operating costs of electrical systems can be borne by the recipients thereby requiring no ongoing subsidy.

Capital costs occur once and can largely be borne by donor country participation or soft loans. Operating expenses continue indefinitely and can rarely be financed with aid or soft loans. For heavily urbanized countries, a continuing subsidy for rural electricity may be economically acceptable since the strong urban economy can support a small rural subsidy for electricity. For most of the Pacific Islands with the majority of their population in rural areas, it may be possible to subsidize a few rural electrification projects but the countries cannot reasonably subsidize operating costs of national rural electrification programs.

In the case of rural electrification for social development, the people using the electricity should pay for all operating costs (fuel, repairs, maintenance, labor, etc.).

Where rural electrification is for the purpose of economic development, the development industry should be capable of bearing the electricity system operating costs without subsidy. Though a subsidy during the early years of operation may be appropriate, subsidies lasting longer than five years should not be required.

The best electrification system for a rural village would be one with minimal operating costs. The initial cost is much less important than the operating costs. A diesel system may have the lowest initial cost but the long term cost can be higher than hydro, solar or biomass fueled power systems.

(b) Maintenance of power systems must be accomplishable by local persons with limited technical training.

A central pool of trained maintenance persons located in a city can only service a few isolated rural electrification projects and then only at high cost. Large scale rural electrification must include a local maintenance capability. The pool of well trained electrical and mechanical maintenance technicians is small and its growth is slow. Either an expensive, large scale, long term technical training programme must be included in a rural electrification programme or the electrification scheme used must allow maintenance by persons with minimal training.

Technically oriented development projects should include staff with the technical and management skills necessary to properly operate and maintain a relatively complex power generation system. On the other hand, electrification systems for social development must be capable of administration, maintenance and repair by minimally trained persons.

(c) Spare parts required are few in number and a stock can be kept locally at reasonable cost.

A major problem with remote power system maintenance is spare parts availability. Even with a large central stock of parts, transport to the remote site is often slow. For rural electrification to meet the social and economic development goals desired, the power must be reliable. Long periods without power waiting for spare parts can destroy the profitability of businesses depending on that power and drastically reduce the social value of rural electrification.

To meet this criterion, the rural electrification programme should be designed around simple, standard generation modules as much as possible. Keeping an inventory of spare parts for a wide variety of different generation systems is very costly. In general, photovoltaic power systems require the smallest spare parts inventory while diesel systems require the largest.

(d) Services initially provided must meet the immediate needs and expectations of the rural populace with a capability of being expanded easily and at reasonable incremental cost to meet increased power requirements as development proceeds.

If rural electrification installations do not meet the minimum expectations of the community, they will not be effective tools for either social or economic development. Neither will installations which have little capability for expansion to meet increased needs. In the Pacific, several attempts at photovoltaic based rural electrification provided only very basic lighting with no provision for adding the capability to operate videos, refrigerators, or other electrical appliances. As time passes and expectations change, those minimal systems are becoming inadequate and strong pressures are being applied by those communities to change to costly diesel generation in order to provide more services. Had the photovoltaic programme been designed with load growth in mind, the increased needs could have been met properly and by conversion to diesel generation.

It is not appropriate to initially oversize rural electrical systems to allow for long term load growth. Oversized systems have higher initial costs, lower operating efficiency and generally higher maintenance costs. It is much better to provide systems which can be upgraded at modest incremental cost, with those costs being mainly borne by those individuals desiring increased services.

Development and Electrification Policy

In developing electrification policy, both economic and socially oriented development should be considered. For economic development, electrification policy should be designed to facilitate increased investment in commercial activity. For socially oriented development, electrification programmes should be intended to improve personal and community health and comfort through such things as improvements in lighting, refrigeration, entertainment, communications, health services, sanitation and water supply.

Rural Electrification and Economic Development

Though electricity is necessary for economic development, there is no evidence that industry is attracted to areas of the Pacific simply because electricity is available.

(a) With the exception of mining and related metal refining industries, the cost of electrical power to industries likely to be located in rural areas of the Pacific Islands is less than 10% of overall manufacturing costs. Much more important to citing rural industry than the presence of electricity are factors of raw material availability, transportation, labor availability and access to markets.

(b) Because electricity is a minor factor in rural industrial development, it is not cost-effective for government to allocate more than a minor amount of development funding for rural electrification. A rural electrification policy directed toward economic development should not attempt to electrify rural areas in the hope of attracting industry; rather the policy should be directed toward providing assistance to industry in providing electricity at the industry site after the major problems of raw material supply, capitalization, marketing and transportation have been solved.

It is recommended that rural electrification policy directed toward economic development be implemented as follows:

(a) The policy should provide, where needed, assistance in the development of the electrical power generation facility and up to five years of subsidy to offset some of the cost of local electricity power production for a rural industry which has met the basic criteria for rural industrial development of adequate capitalization, labor, raw material supply, access to markets and transportation. The amount and type of assistance should be determined on a site by site basis.

Although electrical availability and cost is a factor in the profitability of rural industry, it is a minor one. Assistance by government in development of electrical generation at an industrial site should be viewed in the same vein as short term tax relief: a method of improving profitability to increase the survivability of the business during the first years of its operation. It may be reasonable to provide short term assistance in the development of an electricity supply as an added incentive to commercial development but long term survival of the business is not closely linked to electrical prices. Therefore government should not take on the long term burden of a continuing electrical supply subsidy agreement as there will be little benefit to overall development.

Each site at which industrial development is proposed will have different requirements for electrification and the policy should be flexible enough to be of assistance in all cases.

The willingness of government to provide subsidies should be linked to the willingness of the commercial enterprise to use electricity efficiently. The fact that government is making lower cost power available should not result in waste of power by the project. To receive a subsidy, the project should be required to follow energy conservation guidelines provided by the rural electrification authority.

(b) High capital cost power generation facilities such as solar, hydro or steam power are not recommended for new, stand-alone industrial development type electrification projects. They are recommended, if cost effective, only for industries with a history of five or more years of successful operation.

Experience with rural commercial development has shown that projections for long term electricity needs are rarely accurate. Further, the failure rate for rural development projects is high. The installation of hydro electric, solar photovoltaic, biomass fueled steam power or other high capital cost electricity generation system is not recommended in the initial stages of development of an industrial site. It is more cost effective for government to subsidize the extra operating cost of a diesel plant for the first five years of operation of the rural industry than to invest heavily in a high cost electrical generation facility which will probably prove to be the wrong size or will not be needed at all because the venture fails. Diesel plants are relatively low in cost, can be moved to another site if a venture fails and changing the size of a diesel generation facility is not difficult or prohibitively expensive. On the other hand, hydro or steam generation systems are inflexible as to size and can usually not be economically moved to another site.

The effective life of a diesel facility is on the order of ten years and it is recommended that as soon as a new industrial facility is operational that plans be made for converting the diesel generation facility to one which has a lower operating cost or uses indigenous fuel but that no actual installations be made until the industrial venture has stabilized and realistic electricity use projections can be made.

Though some advantages may be obtained by combining electrification for a rural commercial project and nearby rural homes, two serious problems may arise: (1) If the commercial venture fails it will be necessary to make the politically difficult decision to no longer provide electrical power to the homes previously serviced or the difficult financial decision of continuing to provide electricity from a plant much too large to efficiently provide power to the small domestic load; or (2) the commercial venture is successful making its load increase faster than expected making it necessary to take the difficult political decision to disconnect the domestic users freeing up capacity for the commercial venture or the costly financial decision to immediately increase the generation capacity of the plant just to service low profitability domestic loads. Where possible, it is recommended that domestic users not be integrated into a commercially based rural electrical system until the commercial entity has stabilized to the point where electrical use projections can be accurately made.

(c) It is recommended that any subsidy toward the actual cost of electricity delivered to the industrial facility be for no more than five years and that the amount of subsidy should not result in a lower cost of electricity to the user than that which would be received by a similar industry in an urban area of the country.

The goal of rural economic development policy should be to establish efficient, stable, economically sound businesses in the rural areas. While it is reasonable to provide incentives for the establishment of such businesses, there is no indication that long term subsidies for electrical power are effective in keeping industry in a rural location. There is strong evidence that long term electrical power subsidies tend to encourage an increase in power use without a commensurate increase in productivity resulting in a waste of power and waste of the government money provided to subsidize power.

It is recommended that power subsidies be for no longer than a five year period and that they be subjected to a gradual phasing out with a 33% cut in subsidy each of the last two years. This phasing process reduces the fiscal shock of a sudden loss of subsidy and provides incentives for the gradual improvement of plant facilities to more efficiently use electrical power.

(d) Rural electrification policy should include the provision for technical evaluation services and technical assistance to development projects to insure that the project is designed for the most efficient use of electricity.

Because electricity is not a major cost of production for most rural development projects, little attention is paid by developers to the need for the efficient use of power. If government is to subsidize the power plant installation and part of power production costs for a period of up to five years, the energy agency of government should take part in the project design at the earliest possible stage to examine the energy needs of the proposed facility and offer alternatives to the proposed design which would result in the more efficient use of energy.

The technical assistance should extend to preparing operational guidelines to ensure minimal waste of electrical power through energy conservation measures. Subsidies for electrical power production should be tied to the project's willingness to follow these power conservation guidelines and their proper operation and maintenance of the generation equipment.

It is Recommended that rural electrification policy directed toward social development be implemented as follows:

(a) Subsidies for the capitalization of domestic type rural electrification projects should be provided as required but the cost of operation should not be subsidized.

A typical village electrification project in the rural Pacific is to provide lighting power for 30 to 50 houses. The cost of providing this service may exceed US$1,000 per house. Most rural families do not have access to that much cash. On the other hand, cash is usually already being expended for lighting, generally around US$5 per month with many households spending over US$20 on lighting fuel and lantern maintenance.

Money for capital investment in rural electrification is often readily available through aid in the early stages of rural electrification or through soft loans thereafter. It is therefore reasonable to provide a major capital subsidy for the initial installation though there should be significant investment by the recipient. It is recommended that no less than 20% of the total capital investment be provided by the recipient village. This local investment increases the capability of the country to provide electrification to more persons but more importantly ensures that the recipients feel that they have an investment in the system and therefore some responsibility to ensure that it is properly used.

(b) Periodic fees based on services rendered should be collected. A system for collection which includes an authority outside the community should be provided.

Though capital funding is readily available to Pacific Island governments, it is difficult to obtain funding to cover recurrent costs from outside sources. Since there is an existing cost to villagers for energy in the form of kerosene or benzene fuel, it is reasonable to charge at least a comparable amount for the electrical service that eliminated the need for lanterns and their fuel. The total cost of operation and maintenance of the village electrical system should be borne by the village. Further, the individual family cost should be assessed in direct accordance with the amount of services received. Ideally, power should be metered. That is not often practical, however and service cost is applied according to appliances in service and their power requirements. In the case of individual home power systems, such as solar systems, charges based on the number of installed panels is appropriate.

It is important that the fees be collected on behalf of the rural electrification authority rather than the village. Experience has clearly shown that funds collected by the village for power use rarely is used for maintenance of the system. The pressures on the village treasurer to make the collected funds available for other more immediately urgent purposes appears overwhelming. In no case known to the author has a village fund which was established specifically for maintaining the electric power system lasted longer than six months without having been diverted to other village uses.

The actual ownership of the system should not be with the village but rather with the Rural Electrification Authority. Fees collected should go to the Authority and not be kept in the village though collection under village administration is appropriate. The Authority must enforce payment by users through the clearly visible and punitive means of house disconnection, reduction of services, assessment of village produce or other means. If the Authority does not enforce payment, experience clearly shows that payment will never be received with the short term result being total subsidization of Rural electrification. The long term result is a general degeneration of rural electrification services since the recurring costs are too high to be borne by the Authority.

(c) Domestic type rural electrification should be community oriented and should have community involvement in system design, financing and maintenance.

Experience has shown that electrification projects have the best success rate in communities which have electrification as a priority item in their local development plans.

Electrification should be provided only those communities which clearly express a desire for electrification and show that desire thorough payment of their portion of the system capital investment.

The Rural Electrification Authority should visit the site and meet with villagers several times to ensure that a full understanding is reached by both parties concerning the desires of the villagers for service, the capability of the system to be installed and the relative responsibilities of the authority and the village in installation, maintenance and administration of the project.
For the project to succeed, it is important that villagers participate in the installation and maintenance of the system and the village leadership must be willing to take on that responsibility by providing at least two capable persons from the village for training.

(d) Continuing training programmes for rural electrification system installation and maintenance should be a part of rural electrification policy.
Because it is impossible to properly operate and maintain large numbers of small scale rural electrification projects from a central location, relatively large numbers of persons from the rural districts will have to be trained in the installation, operation, maintenance and repair of the systems.

A training facility specifically to meet that need should be included as an integral part of a rural electrification policy. The facility should be administered by the rural electrification authority though it is reasonable that it be physically a part of an existing teaching institution.

Training should also be provided to the users of rural electricity. That training should be designed to help individuals understand what the electricity system can do and what it cannot. Users should be shown how to make the best use of their appliances and how to get the longest life from their system.

(e) System design should allow for load growth through a reasonable cost system expansion not by initial oversizing.

Although electrical load growth in most of the rural Pacific has been much lower than that of urban customers, there is strong evidence that as more money becomes available in rural areas that load growth does occur. Therefore, rural electrification systems should be designed to allow increases in generation capacity at per power unit costs comparable to that of the original installation.

In grid reticulated systems, it is generally good practice to install distribution wiring of a size large enough to handle at least double the initial village needs. The added cost of increased wire size is very small compared to the cost of wire replacement, particularly if an underground reticulation system is installed. The larger wire size also slightly increases the efficiency of the power distribution system at the lighter loads.

In a small hydro system, it may be appropriate to install a large enough penstock to permit water flows up to the limit of the source or, in the case of a large water source, up to twice the initial village load. Again, the added cost of increased pipe size is small compared to replacement and system efficiency is somewhat improved.

On the other hand it is poor practice to install oversized diesel generation equipment since fuel efficiency is poor on a lightly loaded diesel and maintenance costs much higher per unit of power delivered. Oversizing turbines in a hydro plant also results in lowered efficiency of production as well and is not economically appropriate.

Biomass fueled steam generation systems are particularly inflexible and increasing their operating capacity generally means adding another complete unit. Incremental increases in capacity are not usually practical. For that reason, steam plants are best suited to projects that have reached load maturity and significant load growth is not likely.

Individual solar photovoltaic systems are the most flexible power producers for changing load conditions. Adding or subtracting panels and batteries is simple and no more costly per unit power than the original installation.

Institutional Organization for Rural Electrification

Although it is possible for a government energy department or urban power authority to successfully carry out a few rural electrification projects, any attempt at large scale rural electrification requires a specialist organization.

The Rural Electrification Authority must be capable of managing the funding, installation, operation, maintenance, repair and upgrading of large numbers of small power generation systems.

The Authority must have a dispersed administrative structure due to the remote location of most of its plants.

The Authority must have the capability of training large numbers of villagers with minimal technical knowledge in the installation, operation and maintenance of the remote power systems.

The authority must have access to the financial and technical means to fund, design and repair the systems.

To meet these needs the following are recommended:

(a) It is recommended that a rural electrification authority be established as a quasi-government authority having strong technical links with the existing urban electricity authority and the Government energy agency, but that it be financially and administratively independent.

The exact type of organization should be similar to that of the urban electrification organization which varies from country to country. Its links to the urban electrification organization should be very close in technical matters. Actual sharing of technical personnel may be practical though arrangements for technical services and probably will have to be contractual. Shared facilities such as warehousing, training sites, computer systems, etc. would be an appropriate physical link between the urban and rural electricity agencies.

The administration should not be shared between the two authorities, however, though interlocking boards of directors may be appropriate. Also completely separate should be access to funding whether through private, government or overseas sources.

(b) The rural electricity authority should not duplicate capabilities already present in the existing electricity supply system but should have full access to them.

Shared facilities such as warehousing, training sites, computer systems, etc. would be an appropriate physical link between the urban and rural electricity agencies.

(c) The authority should have close formal links with other organizations relating to the rural environment.

Rural development agencies, development banks, rural affairs bureaus, inter island transport authorities or any other organizations which directly relate to rural development should be represented on a board of directors, an advisory board or have some formal link with the rural electrification authority.

(d) The rural electrification authority should have operational administrative management dispersed to the areas where service is concentrated. Central management should provide direction and oversight but day-to-day operations should be carried out in the rural districts being served.

Each generation installation should be within the two hour surface travel radius of a rural electrification administrator. The size of the administrative facility would be related to the number of users serviced in that administrative area. A single village might have one person contracted as a part time representative of the authority while an island with a large number of users might require a permanent office and several employees.

These administrative centers should be fully responsible for the proper operation of the generation systems in their district, for the collection of user fees in their district, the proper preventative maintenance of the systems under their jurisdiction and the quick repair of failed systems.

The central office should provide policy directives, support services for field offices, central accounting, government interface and financial services. The central office should provide direction and supervision to the field offices but all day-to-day decision making relating to the field installations and users should be done by the field offices.

(e) Community level representation by the Authority at both technical and administrative levels should be formal, paid by the authority rather than the community and rigorously maintained.

The authority must have collection and maintenance persons operating within each electrified community. While those persons are expected to be members of the community being served and may be appointed by the community to work with the Rural Electricity Authority, they must be only responsible to the Authority in their work. They should be formal employees of the Authority and be paid directly by the Authority with no compensation coming from the community itself.

Without this administrative distance between the Authority's representatives in the village and the village leadership, it will be impossible for them to make collections, disconnect systems for default on payment or enforce regulations regarding system modifications.

(f) The authority should have formal, direct links with Government offices obtaining and disbursing aid and soft loan capital funding.

Large amounts of capital will be required for rural electrification and if the authority does not have direct access to those in Government that negotiate for and distribute aid money, it will be unlikely to be able to obtain the sums necessary to properly function.

Usually this means having close ties to the Finance and Planning Departments of government. These close ties can be horizontally through governing or advisory board members or vertically through the government Department that has oversight responsibility for the authority.

A rural electrification agency in most Pacific Island countries will be heavily involved in planning and managing small projects in isolated communities. The manpower and management implications of this case are considered in the annex to this paper.

Design, Construction and Supervision of Small Remote Rural Electrification Projects

Summary

The design construction and supervision of remote rural electrification projects requires attention to detail, a good management structure and technical competence. In the early stages of implementation, assistance may have to be obtained from outside sources but for the programme to be successful and to proceed in an orderly and appropriate manner, it is very important that all outside assistance is carefully supervised and directed toward the goals defined by local management. For this to be possible, a small but competent management team used to working with consultants, aid agencies and technical resource persons must be established. As the system grows, more and more of the functions may be made internal to the organization.

Introduction

Although rural electrification is presently very minimal compared with urban electrification rates, the low urbanization of the Pacific Islands can result in more resources being expended in rural electrification than that for the urban areas. For example, the Solomon Islands have less than 15% of the population in urban areas. If only 20% of the rural districts are electrified, the rural electrification authority will have more customers than the urban authority. Because of the dispersed nature of rural electrification, management control can be maintained only through a dispersed management structure. It is therefore important that the management structure be well defined to allow structurally sound growth in the early days of rural electrification.

Design

Although actual design may not be undertaken by an agency within the country, it is important that the system specifications be drawn up locally. Those specifications may be very detailed or very broad according to the capabilities of the agency providing the specifications but always should include the following:

(a) A detailed description of the expected load. This should include the type and power requirement of appliances expected to be used and their anticipated hours of operation per day. The more detail that can be provided, the more useful this load description becomes to the designer. If possible, actual expected times of operation should be provided and Watt loads for each appliance listed.

(b) The acceptable generation technologies for the site with additional descriptive information regarding the specific site description needed for the generation types listed such as:

   (i) Solar. Any information about the solar energy climate of the island is useful. If there are actual sun measurements available for the site they should be provided. If the buildings to be electrified are heavily shaded that should be noted.

   (ii) Hydro. Hydrological information, site studies and contour maps are useful.

(iii) Diesel. Details of fuel availability, price and acceptable locations for the power house should be provided.

(iv) Biomass-Steam. Type of fuel and its availability should be provided. Acceptable locations of power house.

(c) A map of the electrified area showing buildings to be electrified and the electrical services expected in each. Any areas which cannot be used for power lines should be shown. If the site is particularly hilly, the map should show the topography.

(d) A map showing the relationship of the electrified area to the rest of the country in particular the transport means and frequency from an urban area to the site.

(e) The money and time budget for the project.

Obviously, in order to be able to provide even this limited information, several site visits and discussions with the community to be electrified will be necessary. The quality of the information provided to the designer has a direct relationship to the quality of the design. To attempt to electrify a community without several visits to the community and discussions with many, if not all, the members of the community often results in badly matched systems and loads. This in turn results in inefficient use of available resources and users who are not satisfied with the services provided.

As more and more rural electrification installations are made, sufficient experience will be gained to allow totally internal designs. In the early years of rural electrification, outside assistance will often be needed but it is very important that the local agency be involved closely with the designers. This close involvement insures that the design is proceeding along directions satisfactory to the local agency but also provides agency staff with direct exposure to the design process and what amounts to on-the-job training.

External design assistance may come from several sources. The most common are:

(a) Aid agency consultants. It is not unusual for a project funded by an aid agency to include design services. The quality and, appropriateness of these services varies widely. Also variable is the willingness of these consultants to include inputs from the local agency and to work closely with the agency during the design process. Unfortunately it is common for the aid agency consultant to be totally unfamiliar with Pacific island conditions, to have no understanding of the needs of the community being electrified, and to be unwilling or unable to work closely with the local agency. As might be expected, the resulting design shows this lack of understanding and sensitivity. Be very wary of such arrangements and always seek an outside opinion from a technical organization you trust regarding the appropriateness of a design produced under these conditions.

(b) Equipment sales organizations. Since the equipment sales organization wants his equipment to work properly, it should be consulted regarding designs to insure that equipment is being used within proper operating range. Suppliers should not be relied upon for designs without a design review by a competent neutral technical organization since it is not unusual for their designs to be padded with excess capacity and added unnecessary features. Also, suppliers usually recommend only products which they sell. This may severely limit the choices.

(c) Private consultants. There are good and bad consultants as in any other profession but in general the private consultant is the most flexible and most likely to provide a reasonable cost design that meets the community needs. Also, the private consultant is most likely to agree to directly involve local agency staff in the design process. The private consultant is also the most expensive option.

(d) Public consultants. Design consultants are often available from the United Nations, international banks, aid agencies and non-government aid organizations. It is sometimes possible to utilize a public consultant to design a power system but this type of consultant is generally best at reviewing someone else's design. Usually there is little or no cost involved; as should be expected with any no-cost programme, the quality of service is variable. Getting a timely response is often a problem though some agencies which specialize in energy problems, such as PEDP, can often provide a design review in a matter of days.

Design Cost

As a general rule of thumb, a rural electrification design should not cost more than 10% of the hardware cost. Complex or unusual designs may be higher but on the other hand designs may often be repeated at several-sites thereby sharing the cost over several installations. A two-panel solar installation may cost under $1000 and the design is likely to cost well over the $100 our guideline would permit. However, in a major rural electrification programme, it is likely that there will be several hundreds, if not thousands, of identical two-panel systems. The design cost can then be spread over many installations.

Design Content

The end result of the design phase of a rural electrification project is a set of documents that allows specification for the purchase of all materials for the project and complete directions for the construction and installation of the project. The complete design may be done by one organization or it may be the result of inputs from several organizations. If there is a design review by an outside agency, it should be of the complete design.

Construction

The construction phase includes tendering and purchase of materials, receipt of materials, testing of components, delivery to the site, installation and completion tests.

As with the design phase, this may be accomplished by local government agencies, local contractors, aid agencies, overseas private contractors or a combination of the four. Again, if outside assistance is needed, the private consultant is the most likely to provide services to fit the need but is also the most expensive. Where aid agencies are involved, construction is generally contracted to organizations with little or no input from the rural electrification agency and control is by the aid agency.

Components ordered should include sufficient spare parts for at least two years of repairs (preferably five) and at least 10% extra of all parts which are easily damaged or lost during installation. The cost of including extra mounting bolts in the initial order is far less than the expense of not having that bolt when needed at the remote site.

Phase 1: Tendering

Generally, requesting price quotations for rural electrification equipment is good practice. To be successful, however, specifications must be written in such a manner that anything which meets the specifications you provide is certain to work satisfactorily and the only variable is price.

A second requirement for successful tendering is that the tender documents must be sent to a wide range of probable respondents. It is rarely useful to simply advertise a tender in one or two periodicals. There are no publications which serve a wide enough geographic range of suppliers to make such an advertisement likely to bring in the wide range of respondents desired nor are there specialist publications, like the US-based Commerce Business Daily, that specialize in tender advertisements.

It is no trivial task to locate manufacturers and suppliers of the equipment needed and often assistance should be sought from embassies, trade associations, aid agencies, UN offices and others involved in purchasing equipment overseas.

All tender requests should have a clearly defined response date and that date should be sufficiently far in the future to allow the respondents at least two weeks time to prepare their response. If the request is complex, a month may be needed.

Tender requests should be for CIF (which is the sum of the cost of the item freight to your port of entry and the shipping insurance). It is common for suppliers to quote FOB (which does not include shipping or insurance) and it is important to add a sufficient amount for shipping and insurance to those quotes.

In evaluating tenders, it is important to be sure that all equipment being quoted actually meets your specifications. It is common practice for vendors to quote items that do not meet specifications but have an attractive price in the hope that they will be accepted anyway.

If the specifications have been correctly written and the items quoted meet those specifications, price should be the most important single consideration but should not be the sole criterion used for selecting the winning tender. On the other hand, bad experiences with some products may justify rejection of tenders quoting on those products. For example, a Delco 2000 solar battery may appear to meet the specifications but experience with that particular battery has been so poor in the Pacific that it should not be accepted for a domestic solar system.

The vendors winning the tender should be immediately notified and the ordering process initiated. Those losing the tender should also be notified and it is good practice to provide a list of the winning tenders (with prices) to the losers.

Phase 2: Receipt of Equipment From Vendors

An important activity during the period after orders have been made is delivery expediting. The "management by exception" method is useful here. That is, as long as everything is going right, nothing is done. It is only when something not planned or expected occurs that action is taken to correct the problem. For this to work, it is necessary to have good communications with suppliers so shipping schedules can be continually updated and those suppliers not meeting promised schedules given special attention. Be aware that time is often an expensive commodity and though air freight is expensive, it is sometimes cheaper than the time lost through surface shipment.

When equipment is received, it should be immediately checked for damage and proper operation then placed in a storage location that is appropriate to the item being stored. Storage should be in a secure location even if items of no great value are being stored since the loss of those items could delay the entire project weeks or months turning their loss into an expense far greater than their individual value.

Critical items, or those known to have varying characteristics, such as solar panels, should each be checked to insure that they meet the purchase specifications. Other items should each be checked to insure that they are operating properly. No equipment should be shipped to the installation site without having been fully checked. Defective components comprising over 10% of the inventory are not unusual. If you wait until they have been shipped to the remote installation site, the time wasted and the cost of replacement will both be markedly increased.

It is appropriate to use the installation crew during this testing phase as it will increase their familiarity with the equipment and insure that they have no basis for complaint if parts received at the job site do not function properly.

Phase 3: Shipment to the Job Site

In most cases this will either be overland by truck or on interisland shipping. In either case, all materials should be shipped at the same time and the shipment should be accompanied by a representative of the electrification agency to insure that handling is proper, that the equipment is off-loaded at the right place and that no pilferage takes place.

Upon arrival, the components should be stored in a secure location until the installation crew arrives, which should be in as short a time as possible.

Phase 4. Installation

Work crews should have been trained prior to the actual installation. The training should have included actual practice in installing the same equipment on similar structures.

It is likely that much of the installation labor will be from the communities being serviced by the equipment with no previous experience beyond their training. It is important that experienced, knowledgeable supervisors be included in the ratio of no more than seven inexperienced installers to each experienced man.

Construction supervisors should themselves be supervised by a technically trained, very experienced project field manager. The field supervisor should bear full responsibility of the installations. He should therefore have the power to make changes in the plans, hire and fire personnel and generally make the decisions necessary both for the expected and for the unexpected factors that come into play during the installation process.

Upon completion of installations, the systems should undergo a full spectrum of tests to show that they are functioning as specified. Once this is demonstrated, the installations are tuned over to the operating authority.

The final act of the construction phase is the training of the users in the proper operation and maintenance of their electrical systems. For most stand-alone type systems, insufficient capacity is available for the indiscriminate use of irons, electric fry pans, electric tea kettles and other high demand appliances. It is important that the users have a full understanding of the limitations of their system.

Operational Supervision

Once the system has begun operation, the operational supervision phase begins. In this phase, the supervisory role of the rural electricity implementation agency varies according to how the system operation is handled.

Operator Employees of the Electrification Agency

The recommended mode of system operation is for members of the community being electrified to be trained in the operation and maintenance of the system and then employed by the rural electrification agency to operate and maintain the system. In this mode, the supervisory chain is that of the rural electrification agency.

It is recommended that a minimum of two persons be employed to operate and maintain a rural electrification system in each community with one additional person hired for every seventy-five houses being serviced. Thus in an electrified village of fifty houses there should be at least two rural electrification agency employees responsible for that system. In a village of one hundred houses, there should be at least three persons, on hundred sixty houses, four persons, etc. Note that these persons do not all need to be full-time employees.

The system technicians should not be responsible in any way for collecting fees from users. Experience shows that fee collection can be handled well by either the traditional village structure or by someone entirely outside the village hierarchy. To have the technicians, who are most likely residents of the village themselves, in the position of having to collect fees creates friction with the traditional village leadership and can easily result in unpleasant situations sometimes even resulting in the abandonment of the electrification system.

Area Supervisors

The supervisor above the village operator level should have responsibility for no more than ten communities and all those under his supervision should be on the same island and accessible within two hours of surface travel. For the purposes of discussion, he will be called the Area Supervisor. This mid-level supervisor should visit each installation under his jurisdiction at least once a month-and should be responsible for fee collections though actual collections may be through traditional village leadership structures. In most cases it may be best if he has few family ties in the villages under his jurisdiction since he makes the decision to disconnect service for non-payment or system abuse. His responsibility and power in such matters must be clear and should never be overruled by his superiors in the rural electrification authority on matters of customer disconnects. In the rural electrification management structure, the area manager should be the management focus and primary field decision making position. Upper management should not interfere with his decisions relating to matters undeı his jurisdiction.

The area supervisor is responsible for supplying spare parts, fuel and other supplies to the villages. He must maintain a limited access store and maintain a sufficient stock of supplies and spares to last at least twice as long as the usual period between supply shipments from the central stores. He must be made responsible for those supplies and must keep proper records of disbursements to village operators.

The area supervisor should be an experienced electrical technician if possible and should at least have received considerable training in the maintenance of the equipment under his supervision.

Upper Management

On large islands with more than four or five area managers, it may be necessary to create an island manager position to coordinate maintenance and supply distribution on the island. He should either himself be an experienced technician or should employ a good technician to assist in complex or unusual maintenance and repair operations. This island manager should be more of a resource to the area supervisors than their management superior. For an island with several hundred electrified homes, the requirement for technical services beyond those which can be provided by the operators and area supervisors will be high enough to warrant a full time, on island technician. Smaller islands will have to rely on technicians that are brought in from elsewhere to perform those special tasks, therefore it is good management procedure to assign area managers with the best technical capabilities to islands without resident technicians.

Home Office Management Structure

The management structure of a successful rural electrification authority will be dispersed. In the central office only those persons needed for the support of the field management structure should be employed. Finance, personnel, purchasing, accounting, design and supply functions will have to be centralized but there should be no attempt to provide more than general direction to field management.

The head office of the rural electrification agency will have the following major responsibilities:

(a) Interfacing with government and other development agencies;

(b) Obtaining financing for rural electrification capital investment;

(c) Design of installations;

(d) Selection of new installation sites;

(e) Purchasing;

(f) Stocking of spare parts and operating supplies;

(g) Technical support;

(h) Personnel management; and

(i) Accounting

(j) Training

Some of these tasks may be shared with the urban electricity agency. A minimum of four persons will be needed at low levels of implementation. They would be:

(a) a technical manager who would be responsible for design and technical support;

(b) a business manager who is responsible for purchasing, stocking, accounting and personnel management;

(c) a general manager responsible for inter-agency interfacing, finance and selection of new sites; and

(d) a senior maintenance technician who spends most of his time travelling between installations providing technical assistance to field personnel.