Renewable Technologies for Energy Security: Institutions and Investment in Fiji's Electricity Sector

By

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A thesis submitted for the degree of Doctor of Philosophy of the Australian National University.

RESOURCE MANAGEMENT IN ASIA PACIFIC PROGRAM
CRAWFORD SCHOOL OF ECONOMICS AND GOVERNMENT
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THE AUSTRALIAN NATIONAL UNIVERSITY

2011

Declaration

I, Matthew Dornan, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Resource Management in Asia Pacific Program, Crawford School of Economics and Government, College of Asia and the Pacific, the Australian National University, is wholly my own work unless otherwise referenced or acknowledged (as is the case for part of Chapter 3). This thesis has not been submitted for qualifications at any other academic institutions.

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Part of this thesis has been made publicly available in the form of journal articles and conference papers:

Dornan, M. 2011, Solar-based rural electrification policy design: The Renewable Energy Service Company (RESCO) Model in Fiji, *Renewable Energy*, Volume 36, pp 797-806, Feb 2011

Dornan, M. 2009, Methods for assessing the contribution of renewable technologies to energy security: the electricity sector of Fiji, *Pacific Economic Bulletin*, Volume 24, No. 3, October 2009

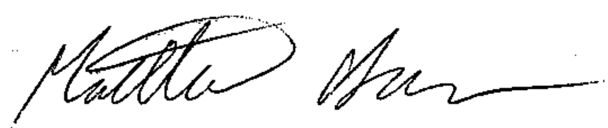
Dornan, M. and F. Jotzo, 2011, Electricity Generation in Fiji: Assessing the Impact of Renewable Technologies on Costs and Financial Risk, Australian Agricultural and Resource Economics Society 55th Annual National Conference, Melbourne, 8-11 February, 2011

Dornan, M. 2010, Assessing the Impact of Renewable Technologies on Energy Security: The electricity sector in Fiji, International Conference on Renewable Energy and Climate Change 2010: Focus on the Pacific, University of the South Pacific, Suva, 24 November 2010

Dornan, M. 2010, Institutional Arrangements for Solar-based Rural Electrification: The Renewable Energy Service Company Program, Fiji Economy Update, University of the South Pacific, Suva and Lautoka, 20-22 July 2010

Dornan, M. 2010, The Institutional Framework Governing Solar-based Rural Electrification in Fiji, Australasian Development Economics Workshop, University of Western Sydney, 11 June 2010

Signed



On the 21st December 2011

Acknowledgments

A number of people provided critical input into this study. I would like to especially thank Frank Jotzo, the chair of my supervisory panel, for his continuous support and advice. Other members of my supervisory panel also provided valuable support, including Ron Duncan, Matthew Allen, and Marjorie Sullivan. Ron was especially helpful in ensuring some of my material was published and presented to a Fijian audience. Theo Levantis provided advice early on that was instrumental in my commencement of this research project.

I am indebted to a large number of people in Fiji. The Department of Energy provided me with valuable information on the energy sector in Fiji. Particularly helpful were Inia Saula, Pecelli Nakavulevu, Susana Pulini, Moape Waqa, and Paula Katirewa. The University of the South Pacific also provided me with a work space during my stay in Suva.

Members of the Rural Electrification Unit made possible my analysis of rural electrification programs, introducing me to rural communities that I would otherwise have been unable to access, and providing me with accommodation in Labasa. Frank Rokowaqa, Deepak Chand, Viliame Silatolu, and Jope Caginibua were especially helpful during my research in Vanua Levu. I would also like to thank Krishn Raj, director of RES Ltd, for our frank and open talks.

My analysis in rural areas would not have been possible without the kind support and hospitality of the people in Dama, Wairiki, Nakawakawa, and Vunivao. I would like to especially thank Paula Valeyaga and his family for their generosity. My good friend and interpreter, Eferemo Campbell Romokosoi, also deserves a special mention for his assistance and patience in seemingly endless interviews.

Lastly, I would like to thank my wife, Susana, for her understanding and patience.

Abstract

Renewable energy technologies have been advocated in Fiji's electricity sector on the basis that they improve energy security and serve as a risk-mitigation measure against oil price increases. This follows a decade of significant oil price volatility and historically high oil prices, which negatively affected the oil-dependent electricity sector in Fiji and other Small Island Developing States in the Pacific. This dissertation examines the extent to which renewable technologies can improve energy security in the electricity grid and in rural off-grid areas of Fiji. The main contributions from the research are a novel empirical analysis of generation cost-risk in the electricity grid; an analysis of institutions governing power sector investment; a survey, interview and focus group-based analysis of rural electricity supply; and an evaluation of implications of the research findings for policy.

In Fiji's electricity grid, threats to energy security are primarily the result of increased generation costs and their impact on electricity prices. Risk is therefore financial. In this thesis, it is assessed using portfolio theory. Detailed data on costs and variability is fed into a stochastic portfolio model, which is developed to analyse the impact of renewable technologies on generation costs and financial risk in Fiji's electricity grid looking forward to 2025. The analysis demonstrates that renewable technologies can be expected to significantly improve the security of electricity supply through diversification, as the cost streams of renewable technologies are neither correlated with those of oil-based power generation, nor strongly correlated with each other. Importantly, investment in hydro, geothermal, biomass and bagasse-based power generation is found to lower expected average generation costs in the electricity grid. The implementation of energy efficiency measures also lowers generation costs and risk in the electricity grid.

Renewable technology investment that is forecast in Fiji's electricity grid is found to fall short of what would be desirable based on the analysis, despite being significant. This investment deficit can be explained by institutional arrangements in the power sector. The research shows that barriers to investment in renewable technologies include political uncertainty, lack of available finance, and historically low feed-in and retail tariff rates. Regulatory reform now occurring is found to be promising in this regard, and is likely to attract increased investment in renewable technologies. Continuing political uncertainty nonetheless remains a barrier to investment, given the regulatory risk it entails.

In rural off-grid areas of Fiji, energy security needs to be understood differently, with fuels such as kerosene commonly used as substitutes for electricity in the provision of services. This dissertation examines energy security and power generation in four rural communities in Vanua Levu (in northern Fiji), where there is widespread use of village diesel generators and household solar photovoltaic systems installed under government rural electrification programs. A survey, interviews and focus group discussions conducted for this dissertation show that un-electrified households were disproportionately impacted by oil price volatility in recent years, due to their reliance on fossil fuels. Power outages in electrified households were also found to be common. For village diesel systems, collective responsibility for financing fuel and maintenance is problematic. Informal norms and governance arrangements at the village level only partially resolve these issues. Solar photovoltaic systems in these communities also commonly perform poorly, primarily as a result of inadequate arrangements for maintenance established by government.

A number of policy implications are identified in the dissertation. Forecast renewable technology investments in the electricity grid are worthwhile in light of their financial and risk mitigation benefits. Regulatory reform now underway and high retail and feed-in tariff rates already in place are facilitating such investment. Policy measures that could further encourage investment in renewable technologies include those designed to strengthen political and regulatory certainty; improve access to finance, land, and renewable energy resources; reform the sugar industry; and support research on renewable energy resources. Mechanisms designed to encourage the use of energy efficiency technologies should also be adopted. In rural off-grid areas, there are strong financial and social benefits from electricity provision, but reform of rural electrification programs is needed.

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Abbreviations

ADB	Asian Development Bank
CDM	Clean Development Mechanism
CFL	Compact Fluorescent Lamps
CRF	Capital Recovery Factor
EU	European Union
DoE	Department of Energy (Fiji)
EIA	Energy Information Administration (US Government)
FEA	Fiji Electricity Authority
FJc	Fiji cents
FLP	Fiji Labour Party
FSC	Fiji Sugar Corporation
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFC	Global Financial Crisis
GNI	Gross National Income
GoF	Government of Fiji
HFO	Heavy Fuel Oil
IAD	Institutional Analysis and Development
IEA	International Energy Agency
IPP	Independent Power Producer
MEPS	Minimum Energy Performance Standards
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
PICs	Pacific island countries
PNG	Papua New Guinea
PPA	Power Purchase Agreement
RESCO	Renewable Energy Service Company
SDL	*Soqosoqo Duavata Lewanivanua* (Fijian political party)
SHS	Solar Home Systems
SOPAC	Pacific Islands Applied GeoScience Commission

SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
SVT	*Soqosoqo ni Vakavulewa ni Taukei* (Fijian political party)
UN	United Nations
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States Dollar
VLIS	Viti Levu Interconnected System

Units of Measurement

J	joule of energy
kW	kilowatt (one thousand watts)
kWh	kilowatt hours
kV	thousand volts
GW	Gigawatt (one thousand megawatts)
GWh	Gigawatt hours
L	Litre
MW	Megawatt (one thousand kilowatts)
MWh	Megawatt hours
TJ	Terajoules (one trillion joules)
V	Volt
W	Watt

Glossary of Terms

bagasse – a by-product of the sugar cane crushing process, bagasse is a form of biomass that can be used to generate electricity.

base load – refers to the minimum amount of electricity that is required at all times, including when demand is lowest.

benzine – a term commonly used for referring to petroleum ether. Benzine is used for lighting in rural areas of Fiji.

biomass – refers to wood or fuel crops that can be used to generate electricity.

busbar cost – is the cost of electricity generation, excluding all distribution and transmission costs.

capital recovery factor – converts an initial investment cost into a stream of equal annual payments using a discount rate.

capacity factor – actual electricity generation as a percentage of possible generation

common good – a common good is a) non-excludable, meaning that it is consumed simultaneously by the public, irrespective of whether individuals contribute resources towards the provision of that good, and b) rivalrous, meaning that consumption of the good by an individual subtracts from its consumption by another person.

distribution – electricity distribution refers to the delivery of electricity from a transmission network to end users.

energy ladder – the energy ladder concept explains the movement towards more efficient sources of energy as income rises.

generation capacity – potential electricity generation from a power plant.

geothermal – refers to power generation using geothermal energy generated and stored below the earth's surface.

kerekere – is a gift exchange system that enables members of a village or kinship group to ask for a range of items from other members of the same group. Reciprocal obligations are established as a result of such gifts.

levelised cost - The levelised unit cost of electricity refers to the cost of generating electricity, averaged over the life of the generation technology. It is expressed in terms of cost per unit of electricity generated, and incorporates the capital cost, operation and maintenance (O&M) costs, and fuel costs of power generation.

mataqali – is an extended kinship group, and is the basis for customary land ownership in Fiji.

monopsony – refers to a situation where a buyer is the single purchaser of a product from several sellers.

negawatt – is a kilowatt of avoided electricity generation.

Pacific Islands Forum – is an intergovernmental organisation which incorporates independent states in the Pacific islands.

Pacific Islands Forum Secretariat – is tasked with implementing the decisions of the Pacific Islands Forum.

peak load – refers to electricity supplied only at times when demand for electricity is at its highest.

sevusevu – is a ritualistic offering of kava to ancestors, commonly used for social purposes in indigenous Fijian communities.

solar photovoltaic – an electricity generation technology which converts sunlight into electrical energy through an array of panels.

soli – a regular collection of money for community purposes, which include assistance for poorer families, purchase of diesel fuel for the generator, and contributions to the provincial council.

solid electricity generation – refers to electricity generation capacity that is reliable and can be used whenever is convenient.

transmission – electricity transmission refers to the delivery of electricity from a power generation plant to a distribution network, which delivers power to end users.

Tui – the village chief in Fiji. In most of Fiji, this position is hereditary and can be occupied only by males from the chiefly *mataqali*.

turaga ni koro – the elected village headman implements decision of the *Tui*, and oversees daily operation of the village. The position is prized given it attracts a small government salary.

unbundle – the term used to describe the separation of ownership and management of electricity generation, transmission and distribution infrastructure.

Yasana – is the indigenous Fijian provincial council in each province of Fiji, and is responsible for overseeing municipal functions for indigenous Fijians.

Yasuva – is an indigenous Fijian grouping that normally equates to a village.

Chapter 1

Introduction

Renewable energy technologies have the potential to reduce vulnerability to oil price volatility and high oil prices in the electricity sectors of Small Island Developing States in the Pacific. This is important for two reasons. Reliance on oil-based power generation among power utilities in the Pacific islands has exposed them to oil price volatility in recent years, threatening energy security as a result. Reliance on "traditional" fuels for lighting and cooking among rural households not connected to the electricity grid has likewise made them vulnerable to oil price volatility, threatening energy security, and forcing some households to reduce energy consumption or adopt inferior sources of energy. This dissertation explores the use of renewable technologies (including energy efficiency technologies) to address such concerns in the Fiji Islands. Chapter one provides the context for this research by providing an overview of Fiji and its energy sector, and discussing oil price volatility and its impacts on Fiji. The chapter also establishes a research agenda, and outlines the analysis that is to follow.

1.1 Introduction

Renewable energy technologies (referred to here as renewable technologies), including energy efficiency technologies, have the potential to reduce vulnerability to oil price volatility in the power sector and facilitate rural electrification in Small Island Developing States (SIDS) in the Pacific (Pacific island countries).[1] Both objectives are important. Reliance on oil-based electricity generation among power utilities has exposed Pacific island countries to oil price volatility in recent years. Energy security, which can be defined as "adequate, affordable and reliable supplies of energy", has been threatened as a result (chapter two includes a more detailed discussion of energy security) (IEA 2007b). Electricity tariffs have risen and power has been rationed in a number of Pacific island

[1] The term "Pacific island countries" refers in this dissertation to the fourteen SIDS member countries of the Pacific Islands Forum, with the notable exception of Papua New Guinea. The Pacific Islands Forum is a regional grouping that includes the following SIDS: the Cook Islands, the Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, the Republic of the Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. Australia and New Zealand are also members of the Pacific Islands Forum, although are not considered Pacific island countries. The discussion in this thesis is in many cases also relevant to Pacific island territories, although this is not explored in this research.

countries, and where electricity is subsidised by governments, oil price increases have had adverse fiscal impacts. Sharp increases in international oil prices have also had adverse consequences for the balance of payments and international reserves.

In rural areas, many households in the region remain un-electrified, and reliant on “traditional” fuels such as kerosene, benzine and firewood for lighting and cooking. Kerosene and benzine are costly, provide inferior lighting services, and have adverse health consequences. Reliance on these fuels also exposes rural households to oil price volatility, threatening energy security, and forcing some households to reduce energy consumption and move down the “energy ladder” by adopting inferior sources of energy (such as replacing kerosene with firewood for cooking).

This dissertation explores the use of renewable technologies to address such concerns in the context of the Fiji Islands. Fiji was chosen as a country where there has been substantial experience with renewable technologies in both the power grid and in rural areas not connected to the grid (off-grid areas). The prospects for renewable technologies are also strong in the Fiji Islands, given available renewable energy resources.

1.1.1 Oil Price Volatility in the Pacific Islands

The economies of Pacific island countries have been adversely affected in recent years by oil price volatility and high oil prices. Record oil prices in 2008 had particularly significant macroeconomic implications. In Fiji for example, the value of oil imports rose from approximately 7 to 17 per cent of Gross Domestic Product (GDP) between 2003 and 2008 (Fiji Islands Bureau of Statistics various years; Reserve Bank of Fiji various years). The effects of these prices on Fiji and other Pacific island economies are detailed in section 1.3.

High oil prices threaten energy security and affect power generation in Fiji and other Pacific island countries. The impact on the power sector is the result of the dependence of Pacific island countries on diesel-based electricity generation (Tumbarello 2008; Wade 2005b). The inflexible nature of electricity tariff determination in many Pacific island countries also means that electricity prices are commonly absorbed by the power utility or government, with adverse fiscal consequences (ADB 2008; Levantis, et al. 2006; Morris 2006; Sanghi and Bartmanovich 2007). Electricity has been rationed in several cases as a result. In the extreme case of the Marshall Islands, the Government declared an economic "state of emergency" in July 2008 when it appeared that electricity generation would cease as a result of the government-owned utility's inability to pay for the diesel fuel required to operate generators (Taiwan stepped in with funding support at the last moment) (Islands Business 2008b).

Investments in renewable technologies are widely advocated in Pacific island states as a response to oil price volatility and high oil prices (Feinstein, et al. 2010). In Fiji, the *National Energy Policy* states that "national leaders have attributed the slow growth in the economy to the unsustainable fuel price increases… prompt(ing) the Government to look for viable alternative energy sources available locally" (Department of Energy 2006a: 7). The Pacific Islands Forum Leaders Communiqué in 2008 similarly: "highlighted the critical importance of efforts to reduce dependence on oil through measures to improve energy efficiency and move towards greater use of renewable energy" (Pacific Islands Forum Secretariat 2008:2). A number of countries, including Fiji, have subsequently established renewable energy targets for their power sectors.

1.1.2 Research Problem

Renewable technologies continue to be endorsed in two areas in the Pacific islands. In the electricity grid, renewable technologies are advocated on the grounds of reducing oil-based power generation, thereby lowering power generation costs and reducing exposure to high oil prices. In rural areas with no power supply, renewable technologies are promoted as a cost effective means of rural electrification.

Despite such support, there has been minimal research on the impact of renewable technologies on energy security in the power sectors of Pacific island countries. Significantly, there has been no published attempt to rigorously measure the impact of renewable technology investment on energy security. There have also been no academic publications on the impact on energy security of institutional arrangements in the power sectors of Pacific island countries. Analysis of rural electrification using renewable technologies has not explicitly considered energy security or the effect of fuel price increases on rural households in the Pacific islands. This dissertation addresses these gaps in knowledge.

1.1.3 Related Research

Literature on the energy sector of Pacific island countries can be categorised as either community/project or national/policy focused. At a national or policy level, there is academic literature on the use of renewable technologies in the electricity sectors of Pacific island countries (see for example Blair 2004; Burnyeat 2004; Marconnet 2007; Mayer 2000; McGregor 2009; Weisser 2004a; Yu, et al. 1996; Yu and Taplin 1997; Yu, et al. 1997). Many of these works have sought to address barriers to the implementation of renewable technologies – an issue discussed in more detail in later chapters. The use of biofuels in Pacific island countries has also been the subject of various papers and theses (Blair 2004; Burnyeat 2004; Ethrington 2006; Martyn 2010; Stauvermann and Kumar 2009). Some academic literature also looks at electricity sector regulation in Pacific island countries and/or Small Island Developing States (SIDS). Much of this literature has been critical of arguments in favour of privatisation and deregulation of utilities in SIDS, pointing to the small size of electricity grids, limited regulatory capacity, and low incomes in these countries (Stuart 2006; Weisser 2004a; Weisser 2004b). This is discussed in chapter four.

There are more reports available from regional organisations and donor agencies. Again, much of this literature is focused on renewable energy development in Pacific island countries. The Pacific Renewable Energy Assessment series for example, prepared for the Secretariat of the Pacific Regional Environmental Programme (SPREP), assesses renewable energy resources at a national level in Pacific Island Forum countries and looks at impediments to renewable energy development (see for example Johnston, et al. 2004;

Johnston, et al. 2005; Wade 2005a; Wade 2005b; Wade and Johnston 2005). A number of multilateral and regional organisations conducted country reporting exercises focused on energy sector issues more broadly in 1992 (World Bank, et al. 1992). There are also numerous consultancy reports on electricity regulation and broader energy security issues in Pacific island countries (see for example in relation to Fiji, Maunsell Limited 2005; SMEC 2009).

At the community and project level, regional and bilateral donors have prepared a large number of reports and working papers on projects in which they have been involved. There is also academic literature focused on community level rural electrification projects in the Pacific islands (see for example Bygrave 1998; Jarman 2006; Outhred, et al. 2004; Waddell and Bryce 1999). Much of this literature uses an interdisciplinary perspective to analyse the problems associated with past donor-funded renewable energy projects. Many renewable-based rural electrification projects have failed as they did not sufficiently consider the social element in technology transfer, nor did they establish appropriate institutional mechanisms in order to ensure project sustainability. Similar problems have affected rural electrification projects around the world (Martinot 2003; Martinot, et al. 2001; Nieuwenhout, et al. 2000; Nieuwenhout, et al. 2001; Retnanestri 2007). These issues are discussed in chapters five and six.

1.2 The Republic of Fiji

1.2.1 Fiji as a Case Study

The Fiji Islands is used as a case study in this research for a number of reasons. The electricity grid in Fiji is one of the largest and most developed grids in the Pacific islands. It has a range of available renewable energy resources due to its geography (for solar, wind, and hydro-based electricity generation) and industrial and human activity (for bagasse and biomass-based electricity generation). There is already significant experience with the incorporation of renewable technologies, which means that the impact of these technologies on energy security can be readily assessed. Renewable-based power generation capacity in Fiji currently includes hydro-power, wind-power, bagasse and biomass.

Exposure to oil price volatility is also an issue in Fiji. In recent years, the share of renewable-based electricity generation in Fiji has declined as a result of growth in demand for power. It fell from 92 per cent in 1995 to 52 per cent in 2010 (FEA 2010; Johnston, et al. 2005). This has meant that a significant amount of power supplied through the electricity grid is generated using oil-based generation, which is costly and increases vulnerability to oil price increases. In response, the Fiji Electricity Authority has implemented several grid-connected projects involving renewable technologies, and has committed itself to further expanding the use of renewable technologies for electricity generation (FEA 2008a; FEA 2008b). These objectives are supported by government in the 2006 *National Energy Policy*.

Fiji also offers a good case study for research into renewable energy in rural areas. There is a large un-electrified rural population resident outside of Viti Levu (Fiji's largest island), which facilitates comparison with other Melanesian countries.[2] There is also significant experience in rural areas with off-grid electrification using diesel and solar photovoltaic technologies, making Fiji an excellent case study for comparing these technologies.

[2] Melanesian countries include Vanuatu, Papua New Guinea, Solomon Islands and Fiji. The indigenous population in the French territory of Noumea is also considered Melanesian. West Papua in Indonesia and East Timor also have significant Melanesian populations.

1.2.2 Overview of the Fiji Islands

The Republic of Fiji (commonly referred to as “Fiji” or the “Fiji Islands”) is a nation in the South Pacific, comprising an archipelago of 320 islands, about 108 of which are permanently inhabited. Fiji is the largest of the Pacific island countries (excluding PNG) with a population of 837,000, and is considered the “hub of the South Pacific”, being the hub for re-exports to other Pacific island countries and the home to regional institutions such as the Pacific Islands Forum Secretariat. It is situated approximately 2,000 km northeast of Auckland and 2,800 km east-northeast of Brisbane, and is neighboured by Tonga, Tuvalu and Vanuatu. The climate in Fiji is tropical, with an average maximum temperature of between 27 and 32 degrees Celsius, and high levels of rainfall concentrated in the “wet” season from November to April.

Approximately half of Fiji’s population lives in urban areas. Almost 80 per cent of the population lives on the main island, Viti Levu, and about 16 per cent lives on the second biggest island, Vanua Levu (Fiji Islands Bureau of Statistics 2007).[3] Much of Vanua Levu and other islands in the Fijian archipelago are sparsely populated. The biggest urban centres (cities for administrative purposes) in Fiji are Suva and Lautoka. Other significant urban centres (called “towns” for administrative purposes) are Nadi, Labasa, and Ba, and the greater Suva areas of Lami, Nasinu and Nausori. Table 1.2.2a contains 2007 census population figures for these centres. All urban centres in Fiji with the exception of Labasa, Savusavu, and Levuka are located in Viti Levu. A map is provided in figure 1.2.2a.

[3] Census figures from 2007 indicate that this concentration of population is set to continue, with strong population growth in urban and peri-urban areas of Viti Levu (especially in the Nausori corridor near Suva), and negative population growth in Vanua Levu and the Lau group of islands (the eastern division). Much of this is the result of internal migration of Indo-Fijians from sugar plantations in Macuata province (in northern Vanua Levu) to Viti Levu, a move fuelled by expiry of land leases.

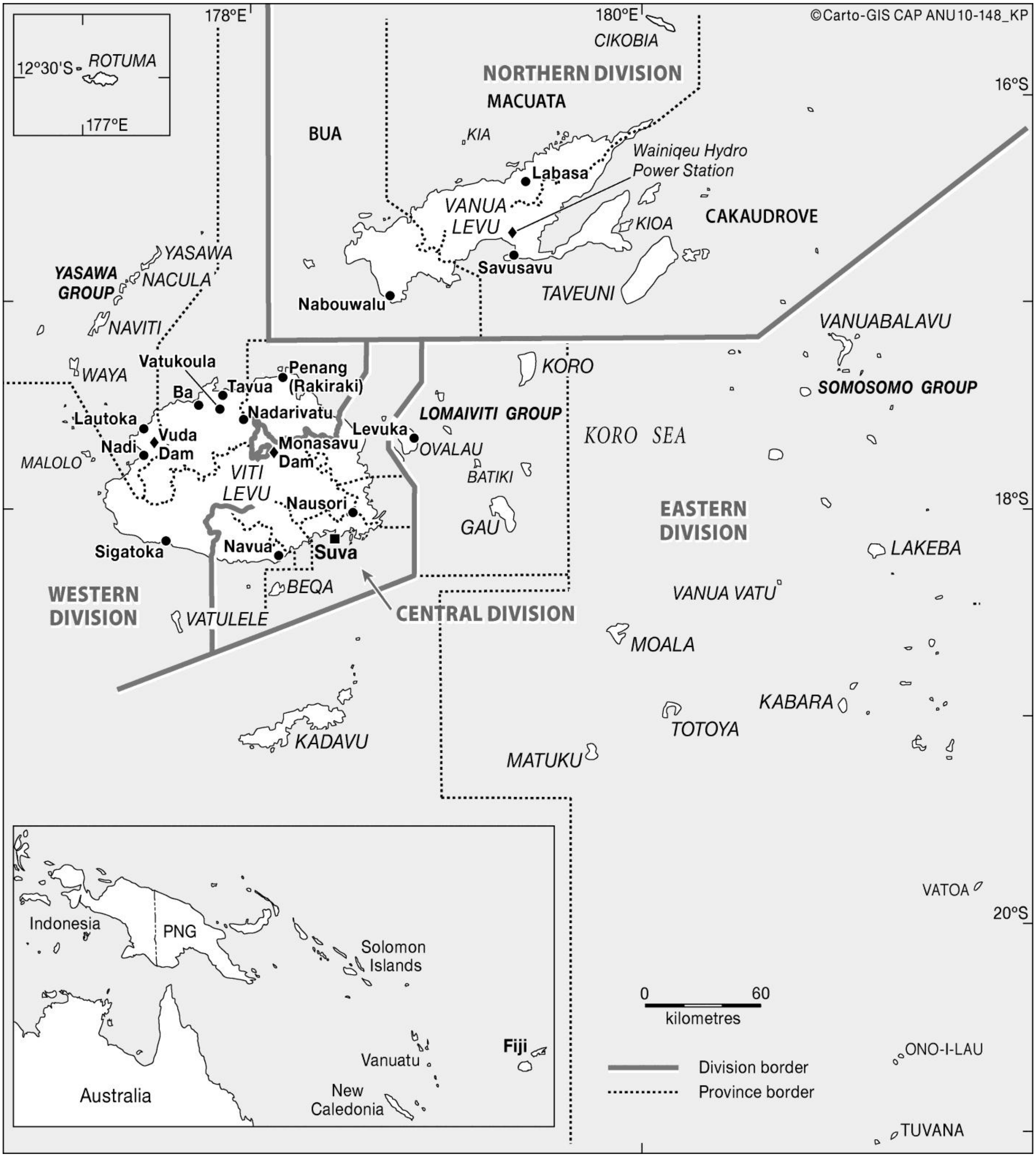
Table 1.2.2a Population Centres in Fiji

City/Town	Population (2007 Census)
Suva City	74,500
- Lami	10,800
- Nausori	24,900
- Nasinu	76,000
Suva (greater Suva)	186,200
Lautoka City	43,500
Nadi	11,700
Labasa	7,700
Ba	6,800
Savusavu	3,300
Sigatoka	1,600
Levuka	1,100
Tavua	1,100

Source: Government of Fiji (2010a)

For administrative purposes, Fiji is divided into four divisions, which are subdivided into 14 provinces (the self-governing dependency of Rotuma is independent of these divisions). Provinces are governed by provincial councils, which perform municipal functions such as garbage collection, and have powers to impose rates on households (subject to approval by the central government). The four divisions have few administrative powers of their own, but serve to facilitate communication between the Government of Fiji and local level governments at the provincial level (commonly in the form of lobbying). Central in this respect is the commissioner of each division, who is appointed by the government of the day.

Figure 1.2.2a Map of Fiji (with location of renewable-based power generation plants)



Source: Cartography Department, ANU

Fiji is a multicultural country, with large indigenous Fijian (or *iTaukei*) and Indo-Fijian populations. Other significant groups include Rotumans, other Pacific islanders, Europeans and Chinese. The respective population of major ethnic groups, as measured in the 1996 and 2007 censuses, is illustrated in table 1.2.2b. The relative size of these populations is changing rapidly, with the Indo-Fijian share of total population declining (from more than half the population prior to 1987) and the indigenous Fijian share of population increasing.

Table 1.2.2b Population by Ethnic Group in Fiji

	1996	2007
Indigenous Fijian	393,575 (51%)	475,739 (57%)
Indo-Fijian	338,818 (44%)	313,798 (37%)
Other	32,957 (4%)	47,617 (6%)
Total	775,077	837,271

Source: Fiji Islands Bureau of Statistics (2007)

In 2011, Fiji had per capita GDP of FJ$5,645 (or US$3,168), making it an upper middle income country.[4] Two industries are of particular importance to the Fiji economy. Tourism accounts for 18 per cent of GDP, generates 35 per cent of export revenue, and directly and indirectly employs approximately 40,000 people (Fiji Islands Bureau of Statistics 2010a; Fiji Islands Bureau of Statistics 2011b; Mahadevan 2009a; Prasad 2010; Prasad and Narayan 2008; Reddy 2008). The sugar industry, which has been declining for over a decade, now accounts for approximately 6 per cent of GDP, earns 9 per cent of export revenue, and directly and indirectly employs around 200,000 people (Fiji Islands Bureau of Statistics 2010a; Fiji Islands Bureau of Statistics 2011b; Mahadevan 2009a; Narayan and Prasad 2003; Prasad 2010; Prasad and Narayan 2008).[5]

Other primary sector industries are also important in Fiji, such as non-sugar agriculture, forestry, and fisheries. Mining, which in recent years has produced minimal economic output in Fiji, is likely to become increasingly important if establishment of a new copper-gold mine in Namosi proceeds (Newcrest Mining Ltd. 2007; Nittetsu Mining Consultants Co. Ltd. 2009). Some manufacturing activity, such as garment production, also takes place in Fiji.

[4] Exchange rate calculations involving US and Fiji Dollars are based on the average exchange rate over the May 2007 to March 2011 period (where FJ$1 = US$0.561295) unless otherwise stated.

[5] Estimates of employment in the tourism and sugar industries vary significantly. Government estimates employment of 23,000 people in the tourism industry and 50,000 in the sugar industry are considered misleading by a number of authors, given linkages with other economic sectors and multiplier effects in the economy (Narayan and Prasad 2003). The estimates provided here are based on Narayan and Prasad (2003), Mahadevan (2009a), and Prasad and Narayan (2008).

The Fijian economy has performed poorly in recent years, as illustrated in table 1.2.2c. This is partly the result of political instability, which is detailed below. The size of the economy has decreased after every period of political instability (the government was overthrown in coups in 1987, 2000, and late 2006). Particularly worrying is the continued poor performance of Fiji's economy several years after the 2006 military coup. Low levels of investment are primarily responsible. Successive governments have established investment targets of 25 per cent of GDP, however actual investment since the 1987 military coup has averaged approximately 15 per cent of GDP, with private sector investment only accounting for about 5 per cent of GDP since the early 1990s.

Table 1.2.2c Real GDP Growth in Fiji (Percentage) (2005 constant prices)

1971-86	1987-90	1991-99	2000	2001-05	2006	2007	2008	2009	2010
4.12	-0.94	2.76	-1.66	2.45	1.5	-1.1	-0.4	-1.9	-0.4

Source: Fiji Islands Bureau of Statistics (2010a; 2011a); Reserve Bank of Fiji (various years);

The Government of Fiji is also in a difficult fiscal position. Since 1992, it has incurred budget deficits in every year with the exception of 1998 and 2008 (the 1998 budget was in surplus only if debt repayments are excluded). The result is that government debt is now 57.7 per cent of GDP. The continuation of budget deficits by the present government means that government debt is now significantly higher than in 2007, when it was 49.9 per cent of GDP (Government of Fiji 2010a).

The decline of the sugar industry since 1994 has been particularly significant for Fiji, given the large number of people that depend on the industry for their livelihoods. Exports of sugar and molasses have declined from FJ$505.8 million in 1996, to FJ$207.9 million in 2009 (when both figures are measured in 2009 $FJ).[6] This is the result of inefficiencies and poor management in the Fiji Sugar Corporation (FSC), which has a monopoly on the purchase of sugar cane from farmers for milling operations, and the removal of the EU's

[6] Exports of sugar collapsed in 2010, as a result of mill breakdowns, management problems at the Fiji Sugar Corporation (FSC), conflict between FSC and sugar cane growers, and continuing rural-urban migration by Indo-Fijians from cane growing areas. Exports of sugar cane and molasses measured just FJ$89.3 million (in 2009 $FJ) in 2010.

preferential price quota for Fijian sugar.[7] It is also the result of the expiry of land leases, which have historically enabled Indo-Fijian tenant farmers to work the land of indigenous Fijians.

The land issue is significant given that indigenous Fijians retain customary ownership of 87.9 per cent of all land in Fiji (such land is "inalienable" and cannot be sold). In contrast, government land accounts for 3.9 per cent of land in Fiji, freehold land for 7.9 per cent, and Rotuman land for 0.3 per cent (Fiji Islands Bureau of Statistics 2007). The expiry of land leases and failure to renew them has resulted in migration of Indo-Fijians to urban areas, with the subsequent growth of "squatter settlements" (Gounder 2005; Government of Fiji 2007b; Kiddle 2010; Narsey 2006; Narsey, et al. 2010). The issue of land leases has also been a barrier to investment in the past (this is discussed with reference to the power sector in chapter seven), and has fuelled political and ethnic divisions (highlighted below).

1.2.3 Fiji: a Recent History

Fiji became independent from Britain in 1970. The British colonial inheritance includes consolidation of Fiji as a nation state through the spread of religion, language (Bau Fijian), and so-called "traditional" governance structures (many of which were taken from the small island of Bau and imposed on the rest of Fiji). Indian farmers were also brought to Fiji under the colonial administration to work on sugar plantations in the late nineteenth and early twentieth centuries. The legacy of this migration has been political instability and conflict driven by ethnic divisions (Prasad 2004; Scarr 2008).[8]

[7] The EU has purchased sugar from Fiji and other African, Caribbean and Pacific (ACP) nations for prices three to four times the world prices since 1975 (Levantis, et al. 2005). The EU is removing these subsidies under pressure from the World Trade Organisation, reducing the price paid for Fijian sugar by 5.1 per cent in 2007, 9.2 per cent in 2008, and 21.7 per cent in 2009. The current purchaser of Fijian sugar, Tate and Lyle, has now signed an agreement with FSC to purchase sugar from 2008 for prices above the world price, which should provide the Fiji sugar industry some time to reform (Mahadevan 2009a; Mahadevan 2009b).

[8] Tensions between indigenous and Indo-Fijians were present before independence. Indigenous Fijians were cautious about independence from Britain and argued against a common roll electoral system, fearing domination by the larger Indo-Fijian population. Indo-Fijians on the other hand welcomed independence and pushed for a common roll electoral system. Many Indo-Fijians were resentful at their treatment and exclusion from power under the colonial administration (Lal 2008; Scarr 2008).

Fiji's first constitution enshrined a Westminster political system based on a communal/common vote system, with both "common seats" in parliament open to members of all ethnic groups, and "communal seats" restricted to members of particular ethnicities (Lal 2008). The first prime minister of Fiji, Ratu Sir Kamisese Mara, was leader of the multi-racial Alliance Party, which despite being dominated by indigenous Fijians, was popular among both ethnic groups. In 1987, a new government was elected as a result of economic problems and the subsequent implementation of unpopular public sector reforms. The new coalition government, which was led by an indigenous Fijian politician, included the National Federation Party, an Indo-Fijian party that had the greatest number of seats in the coalition.[9]

The Fijian military, a primarily indigenous Fijian institution, reacted by overthrowing the government in two coups in 1987.[10] The new leader, Lieutenant Colonel Sitiveni Rabuka, went about implementing an aggressively pro-indigenous agenda, which included establishing a new constitution that enshrined indigenous Fijian political supremacy (despite a larger Indo-Fijian population), reorienting government spending to favour indigenous Fijians, and implementing a range of affirmative action policies. Many Indo-Fijians migrated to New Zealand and Australia in subsequent years (Lal 2006).

The overthrow of the government in 2000 had its origins in the establishment of a new constitution in 1997, which removed many of the pro-indigenous Fijian provisions of the 1990 Fiji Constitution. This set the scene for the electoral victory in 1999 of the People's Coalition, which was dominated by the (Indo-Fijian) Fiji Labour Party. Mahendra Chaudhry became the first Indo-Fijian Prime Minister as a result. In 2000, a bankrupt indigenous Fijian businessman by the name of George Speight and a small group from the military took the government hostage in Fiji's parliament. The group had the support of many indigenous Fijians. The president dismissed the government and resigned. The

[9] The Prime Minister, Timoci Bavadra, was also disliked by many indigenous Fijians given his origins in the west of Fiji. The indigenous centre of power has traditionally been situated in the eastern confederacies.

[10] After the overthrow of the democratically elected NFP government, Rabuka handed power to the Governor-General, Ratu Sir Penaia Ganilau, with the expectation that he would implement a pro-indigenous Fijian agenda. When Ganilau sought four months later to reinstate the old constitution, Rabuka led a second military coup. In December, he handed power to an interim administration led by Ganilau and Mara, but retained a number of government portfolios and (importantly) his role as head of the military. Rabuka needed these figures given their traditional chiefly status and public support, while Ganilau and Mara could not depose Rabuka for fear of a third military coup. Rabuka was elected Prime Minister in 1992.

military, which was divided in its support for the coup, handed power to an interim indigenous Fijian administration (Lal 2006).

Laisenia Qarase became prime minister as a result of the 2000 coup and won two subsequent elections in 2001 and 2006. His government implemented a pro-indigenous agenda, establishing affirmative action policies and directing government resources towards indigenous Fijians. These policies, together with pardoning of coup perpetrators (which was later reversed), drew criticism from Commodore Josaia Voreqe (Frank) Bainimarama, the head of Fiji's military. Bainimarama was an avowed multi-racialist, who disapproved of "the politics of race".

The military staged a coup in December 2006, with Bainimarama appointing himself as interim Prime Minister one month later. The interim government removed opponents from government posts and installed its own supporters, many of whom are members of the Fiji military (Fraenkel 2009). In 2009, the Fiji Court of Appeal ruled that the military coup was illegal and that new elections should be held. The interim government subsequently abrogated the constitution and dismissed the judiciary.

The interim military government remains in power today. It has stated that it will hold elections in 2014, once its reform agenda is complete. The reform agenda includes establishment of a new constitution, designed to move Fiji away from divisive race-based politics (Nasiko 2011). Important also to the interim government's reform agenda are land tenure arrangements. The government aims to address non-renewal of agricultural leases by encouraging the lease of indigenous Fijian land. Reforms implemented to date enable landowners to lease land for periods of 99 years and break the monopoly of the Native Land Trust Board over administration of land lease agreements (Government of Fiji 2010a).[11] It is too early to tell whether this strategy will succeed in reviving Fiji's agricultural output, especially in the sugar industry.

[11] The Native Land Trust Board (NLTB) previously administered all leases of indigenous land. A majority of its board members were selected by the Great Council of Chiefs, a body that has been emasculated by the interim military government given its criticism of the coup. The NLTB has in the past been an aggressive advocate of indigenous Fijian interests (Lal 2006).

1.3 The Energy Sector in Fiji

1.3.1 Overview of Fiji's Energy Sector

Fiji is heavily dependent on fossil fuels for its energy requirements. All petroleum oil consumed in Fiji is imported in a refined state by one of three multinational oil companies. Significant amounts of fuel are re-exported to smaller neighboring Pacific island states. The Fiji Department of Energy estimates that in 2004, consumption of fossil fuels in Fiji amounted to 463 million litres, accounting for approximately 75 per cent of total energy consumption (measured in terms of terajoules). The transport sector is responsible for a little over 50 per cent of total petroleum consumption in Fiji (Department of Energy 2010; SMEC 2009). Between 17 to 25 per cent of petroleum is used to generate electricity.[12] Other important sources of energy are hydro-power, bagasse in the sugar industry, biomass in the timber industry, and traditional biomass consumed in rural communities.

Fiji's economy is very oil intensive, meaning a large amount of oil is consumed for every dollar of income that is generated. This is largely a result of Fiji's reliance on long distance transportation for imports and exports, and the importance of various energy-intensive activities such as fishing, timber production, mining, and sugar processing (Levantis 2008a, 2008b). The oil intensity of GDP for Fiji and a number of other economies is provided in table 1.3.1a. The table shows that Fiji has among the highest oil intensity of production in the Asia-Pacific.

[12] There is significant variation in estimates of the proportion of fuel used for electricity generation. Annual fuel consumption by the FEA alone comprises between 10 and 17 per cent of total retained fuel imports in any given year (FEA 2002; FEA 2003; FEA 2004; FEA 2005; FEA 2006; FEA 2007a; FEA 2008a; FEA 2009a; FEA 2010; Fiji Islands Bureau of Statistics various years). To this figure must be added fuel consumed by industry to generate its own electricity, which is considerable (GWA 2011). Estimates using Department of Energy data are unreliable, given anomalies in the data (Interviews with Department of Energy staff, November and December 2009 ADB 2009b; Johnston, et al. 2005; SMEC 2009). Those estimates suggest that only 12 per cent of petroleum was consumed by the electricity sector in 2007-09 (ADB 2009b; Kumar 2010; SMEC 2009). This is contradicted by reliable statistics from the FEA and the Fiji Islands Bureau of Statistics. Johnston et al. (2005) argue that a much higher percentage of imported petroleum fuel is used for electricity generation (24 per cent).

Table 1.3.1a Oil Intensity of Production among selected Asia-Pacific economies (tonnes of energy equivalent/US$1,000 GDP)

Pacific island economies / Other SIDS	Oil Intensity of GDP
Fiji	0.31
Solomon Islands	0.33
Vanuatu	0.14
Samoa	0.17
Papua New Guinea	0.25
Maldives	0.69
Asian economies	
India	0.20
China	0.23
Indonesia	0.28
Malaysia	0.23
Philippines	0.29
Bangladesh	0.07
Iran	0.40
Cambodia	0.05
Laos	0.07

Source: Balachandra and Mongia (2008)

Dependence on oil in Fiji and other Pacific island economies is made more problematic by the high prices paid for petroleum products in these countries. Retail fuel prices are determined by refining costs, transport and distribution costs, the price of crude oil, and government taxes and subsidies. Transport costs are very significant in Pacific island countries, given diseconomies of scale (shipments are typically small) and handling in multiple ports. They are highest in the micro Pacific island states, where fuel from Singapore must first pass through Fiji or Guam. Nonetheless, prices are also high in Fiji when compared with the Mean of Platts price for oil in Singapore (from where fuel is imported in Fiji) (ADB 2009b; Castalia 2004; Kumar 2010; Levantis 2008; Levantis, et al. 2006; Sanghi and Bartmanovich 2007). This is illustrated in table 1.3.1b.

Table 1.3.1b Price of Petroleum in Fiji, June 2009 ($US per litre)

Price of crude oil (Mean of Platts, Singapore)	Price of petroleum excluding taxes/import duties	Retail petroleum price
0.44	0.70	0.99

Source: ADB (2009b)

The vulnerability of Fiji and other Pacific island countries to oil price volatility is confirmed by a 2007 UNDP study that measured vulnerability to oil price increases among countries in the Asia-Pacific. Countries were ranked in order of vulnerability on the basis of economic strength, including balance of payments and fiscal positions (which indicate ability to afford oil imports); and dependence on oil for economic activity (Balachandra and Mongia 2008; UNDP 2007b). All four Pacific island countries included in the study (not including PNG as a Pacific island country) were found to be among the seven countries "highly vulnerable to oil price increases".

In an update of that study, the ADB in 2009 included other Pacific island countries and used more recent data to rank economies in terms of vulnerability to oil price volatility. The seven Pacific island countries included in the ADB study were among the 10 most vulnerable economies. Fiji was ranked the third most vulnerable Pacific island country, as illustrated in table 1.3.1c. The high levels of vulnerability of Pacific island countries were due to: (i) economic indicators, including high current account deficits, narrow export bases, high levels of government debt and low per capita GDP; and (ii) oil dependence, illustrated by the high oil intensity of GDP, a lack of domestic oil production, and the high prices paid for fuel (ADB 2009b).

Table 1.3.1c Oil Price Vulnerability Index: Rankings of Pacific island countries (excluding non PICs)

Ranking	Country
1	Kiribati
2	Tonga
3	Fiji
4	Vanuatu
5	Solomon Islands
6	Samoa
7	Papua New Guinea

Source: ADB (2009b)

1.3.2 The Electricity Sector in Fiji

The electricity sector in Fiji incorporates the electricity grid and off-grid power generation in rural areas. Electricity generation in both grid and off-grid areas is vulnerable to oil price volatility, given reliance on oil-power technology.

The electricity grid involves significant oil and hydro-based electricity generation. [13] The large share of hydro-based generation means Fiji enjoys significant renewable-based electricity generation when compared to other Pacific island countries. Depending on rainfall patterns, hydro-power generates between 48 and 65 per cent of Fiji's grid-supplied electricity in any given year. Oil-based generation provides most of the remainder. Independent power producers (IPPs) normally provide about 2-3 per cent of Fiji's electricity, generating power from bagasse (in the sugar industry) and biomass (in the timber industry). This power is sold to the Fiji Electricity Authority (FEA), a state-owned power utility with a monopoly on the retailing and distribution of power in Fiji. Wind and solar technologies provide less than 1 per cent of electricity supply. Power generation shares for 2010 are shown in table 1.3.3a.

[13] The term "oil-based electricity generation" is used in this dissertation to refer to the generation of electricity using fossil fuels. In Fiji, this means electricity generation using diesel, and more recently, Heavy Fuel Oil (HFO).

Table 1.3.3a. Grid-Based Electricity Generation in Fiji, 2010

	Hydro-based generation	Oil-based generation	Biomass and bagasse	Wind and solar
Electricity Production in 2010 (GWh)	413.6	415.1	20	6.4
Percentage of Total Generation	48.4	48.5	2.3	0.8

Source: Fiji Electricity Authority (Annual Reports, 2000-2009)

The proportion of oil-based electricity generation has increased since the late 1990s, as demand for power has grown, rising from 15 per cent of total generation in 1999 to 48.5 per cent in 2010. The relative increase in oil-based power generation has exposed grid-based electricity generation to oil price volatility, increasing power generation costs and impacting FEA finances (this is described further in section 1.3.3 and in chapter three).

Residential electricity generation in off-grid areas of Fiji is insignificant in terms of power generated when compared to the electricity grid.[14] Nonetheless, census data indicate that 15 per cent of Fiji's population is dependent on off-grid electrification systems. Another 11 per cent of the population has no electricity supply whatsoever. High fuel prices have an impact on these rural communities, given reliance on "traditional" fuels for lighting and cooking, fossil fuels for transportation, and the use of fuel-based electricity generators in many rural communities. The energy situation for households in off-grid rural areas is discussed in chapter five.

[14] Exact figures are not available. Electricity consumption among households not connected to the grid is likely to be small. Approximately 15 per cent of the population uses off-grid systems, and these are generally operated for several hours each day. For the 6 per cent of households connected to a diesel generator, Johnston, et al. (2005) estimate consumption among individual households of 501 Wh per day. This amounts to approximately 1.9 GWh per year across Fiji. In the same study, Johnston, et al. (2005) estimate that average electricity generation in Government Stations (explained in chapter four) is 216 MWh. Total power generation in the seven Government Stations in Fiji is therefore likely to be approximately 1.5 GWh per year. Electricity consumption among commercial and industrial businesses is much higher than these figures. The tourism industry is likely to generate significant amounts of power for resorts that are not connected to the grid. Industry also generates much of its own electricity; although in most cases enterprises are also connected to the electricity grid (these entities are not considered "off-grid" here).

1.3.3 The Impact of Oil Price Volatility

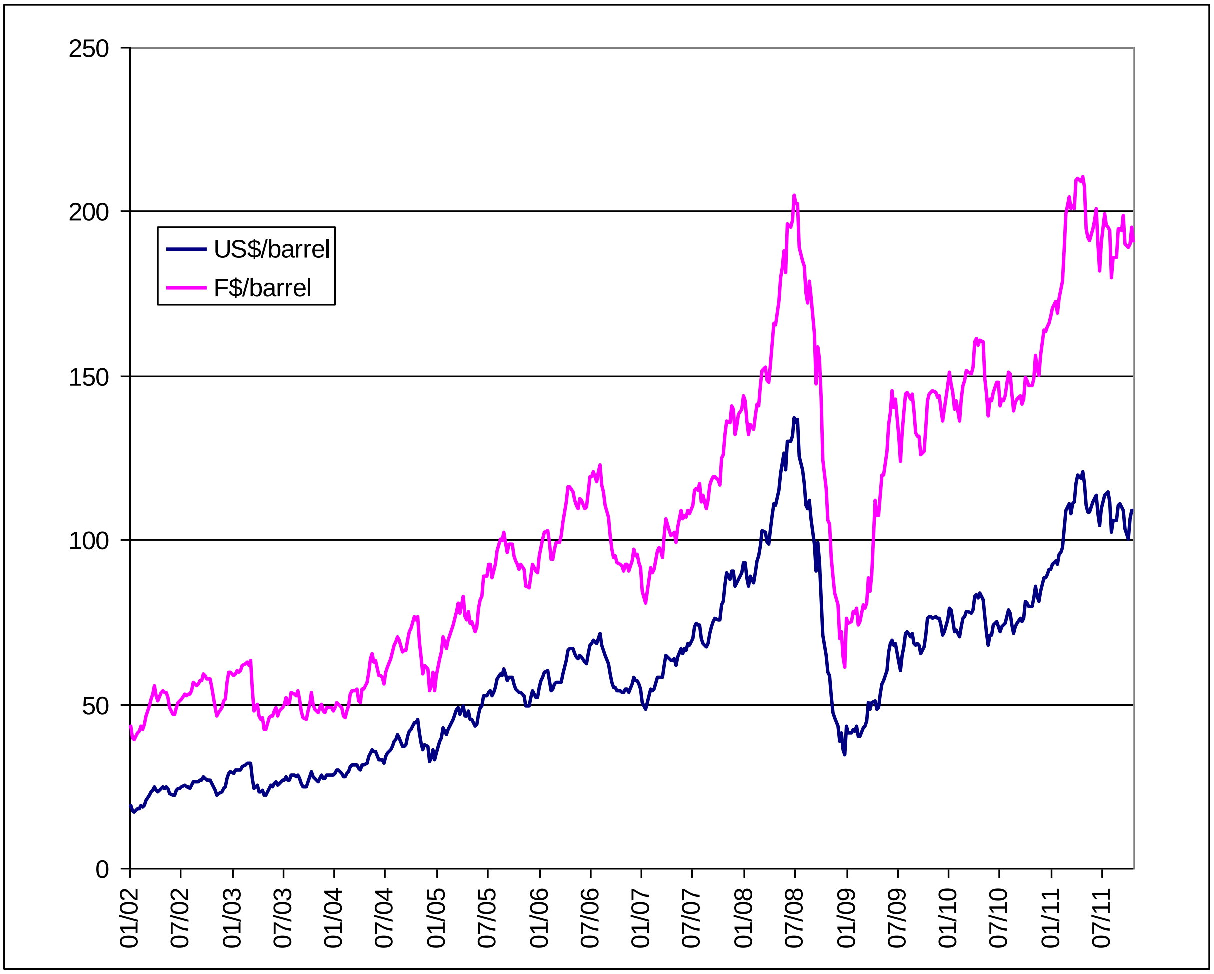
Oil Price Volatility

Investments in renewable technologies in Fiji and other Pacific island countries have been advocated in response to oil price increases and volatility. Movements in the price of crude oil are illustrated in figure 1.3.3a in both US and Fiji dollars. Prices more than doubled between 2002 and 2005, before increasing even more dramatically from 2007 to 2008. Prices then collapsed in response to the Global Financial Crisis (GFC) at the end of 2008.

The impact of oil price volatility remains a relevant issue in Fiji and other Pacific island nations. International oil prices in 2011 increased to levels near to those seen in the 2008 price spike, as a result of the post-GFC economic recovery (and surpassing it when measured in Fiji dollars, given a 20 per cent devaluation of the Fiji dollar in 2009).[15] The underlying structural reasons for high prices and price volatility remain; including the slowing of increases in oil production (and possible production decreases), and high demand for oil in developing countries (especially China and India) (IEA 2008; IEA 2009; IEA 2010).[16]

[15] This recovery is in jeopardy at the time of writing due to the debt crisis in Europe.
[16] Future oil price movements and implications for energy security are discussed in chapter two (section 2.2.2).

Figure 1.3.3a Average Global Oil Price, January 2002 – October 2011 (weekly all-countries spot price FOB weighted by estimated export volume)*

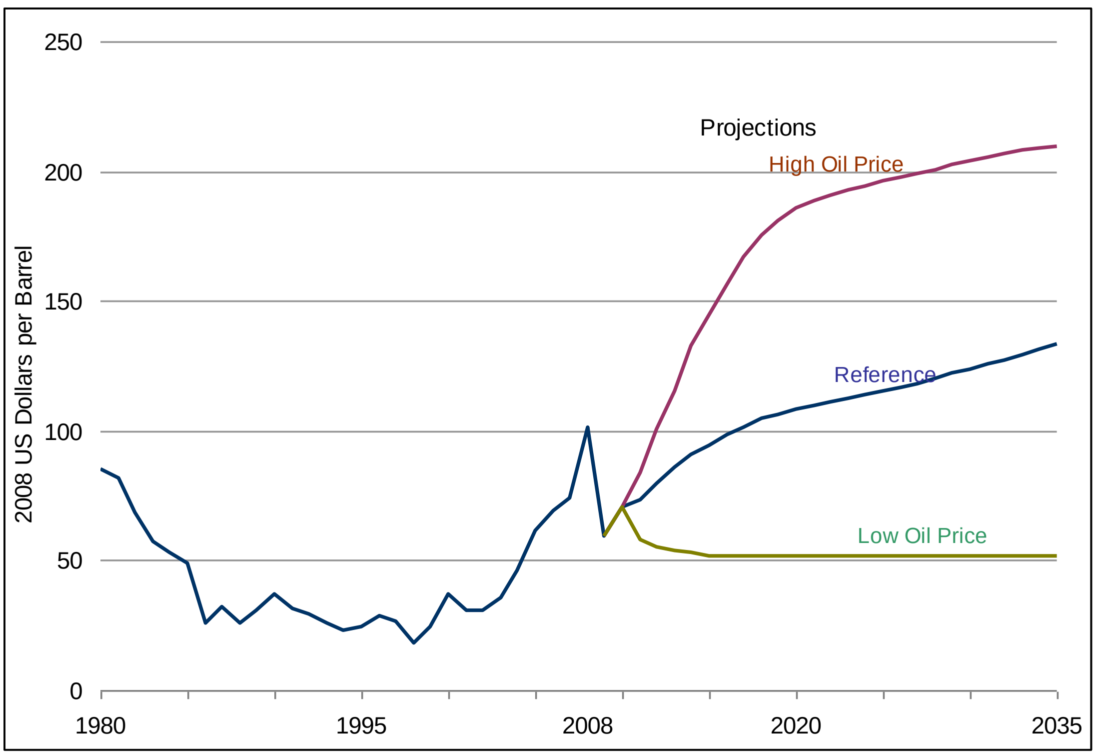


*Note: This figure does not show the price of oil in Fiji, which is likely to be higher as a result of transport costs.
Source: Oil prices in Fiji dollars calculated by the author using daily exchange rates and oil prices (in US dollars) from the Energy Information Administration (2011b), http://tonto.eia.doe.gov/.

There is an emerging consensus that oil prices in the coming decades are likely to be higher and more volatile than in previous decades (EIA 2010; EIA 2011a; IEA 2008; IEA 2010). The IEA Chief Economist has argued that: "the era of cheap oil is over" (as cited in The Economist 2009). The IEA has forecast that under current policies, oil prices will reach US$135 per barrel by 2035 (IEA 2010). The United States Energy Information Agency had previously set a very similar forecast of US$133.22 (2008 USD) per barrel of oil by 2035 (EIA 2010). It has now lowered that figure to US$124.94 (2009 USD), based on its prediction of declining oil consumption resulting from more stringent efficiency standards, and the production of biofuels and non-conventional oil (EIA 2011a).[17] The figure nevertheless represents a substantial increase on the average oil price over the last two decades.

The departure of future oil prices from historical trends is illustrated in figure 1.3.3b. The use of three reference scenarios by the Energy Information Agency (EIA) is indicative of the unpredictability of future oil price movements. Oil prices are influenced by a myriad of interlinked factors, including economic development, government policies (such as policy related to climate change), technology innovation, and fossil fuel resources. Developments in any of these areas influence the price of oil.

Table 1.3.3b Average Annual World Oil Prices Forecast by the EIA, 2010-2035 (including historical prices to 2010)



Source: Adapted from EIA (2010)

Predictions of high oil prices in the future are based on increasing demand for oil, which is the result of world economic growth, especially in China and other Asian countries, coupled with static, and potentially declining, supplies of oil. Experience in a number of

[17] All prices are for Low Sulfur Light Crude Oil.

countries suggests that in the long run, world oil production will "peak" once half of ultimately recoverable oil is extracted.[18] After this point, production will decline, with commensurate increases in price (Campbell and Laherrére 2007; Hubbert 1962; Scrace, et al. 2009).[19]

Both factors are expected to place upward pressure on oil prices in coming decades. The same factors are likely to result in increased oil price volatility, given a lack of spare production capacity. As a result, prices should rise immediately and significantly when production facilities close due to natural disasters or political instability. Both the IEA and EIA therefore predict increasing oil price volatility in future decades (EIA 2010; EIA 2011a; IEA 2008; IEA 2009; IEA 2010). This volatility is very relevant to an analysis of risk in Fiji's electricity sector, as discussed below.

Impacts of Oil Price Increases

Oil price volatility affects Pacific island countries in a number of ways. High oil prices increase the import bill of Pacific island countries, worsening their terms of trade and adversely affecting the balance of payments.[20] The terms of trade of Pacific island countries worsen because exports do not increase in price to the same extent as imports. Sugden (2009) documents the worsening terms of trade that resulted from increases in the price of oil and food in 2008. He shows that in the case of some Pacific island countries, terms of trade worsened by between 4 and 8 per cent of GDP (meaning that the value of net imports increased by between 4 and 8 per cent). Kiribati was the worst affected Pacific island country, with its terms of trade deteriorating by over 10 per cent of GDP. Fiji's terms of trade worsened by 3 per cent of GDP. Approximately 90 per cent of the terms of trade

[18] The focus of peak oil theory is on oil that is ultimately recoverable, both technically and in an economically viable manner. This is significantly less than the amount of oil that remains in the earth's surface, much of which will never be extracted due to technical and financial barriers.

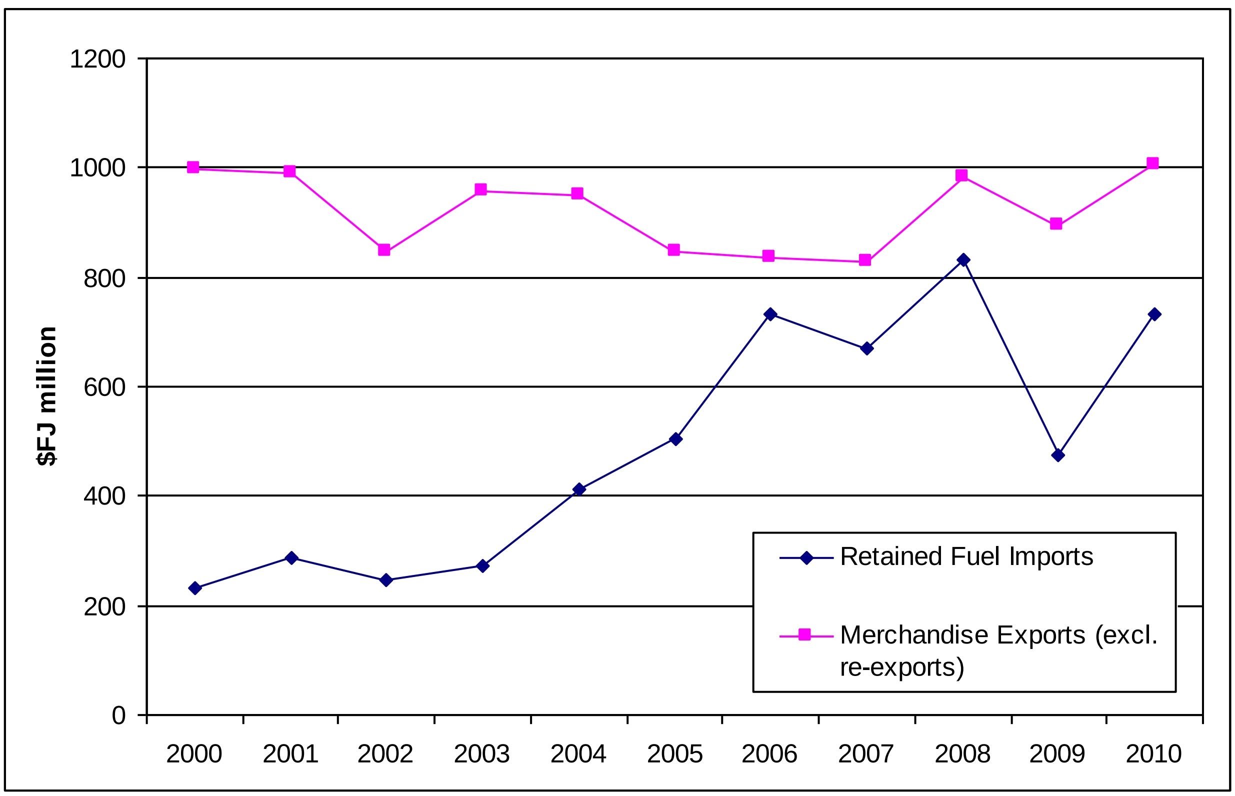
[19] It is likely that oil production worldwide will peak sometime before 2030, with many analysts suggesting a peak prior to 2020 (Campbell and Laherrére 2007; IEA 2010; Smil 2006; Sorrell, et al. 2009). The impact on prices of such a peak will in part depend on alternatives, including both renewable technologies and non-conventional oils such as the Canadian tar sands, oil shale reserves and coal-to-fuels. The timing and implications of peak oil are discussed in more detail Appendix A2.1.

[20] This occurs because: (i) demand for oil is inelastic in the short run (meaning that demand for oil in the short run does not respond significantly to changes in the price of oil), and (ii) all oil consumed in Pacific island countries is imported.

impacts were due to oil price movements, with increases in the price of food responsible for the remainder.

The impact of oil price volatility on imports to Fiji is illustrated in figure 1.3.3b and table 1.3.3a. Oil imports are compared to merchandise exports and GDP, as this provides an indication of Fiji's ability to pay for its imports.[21] As a result of high fuel prices in 2008, retained fuel imports (or fuel that is imported for consumption in Fiji) was equal to 85 per cent of all merchandise exports and 17 per cent of GDP in Fiji. In 2006 retained fuel imports were also high, as a result of record oil-based power generation by the FEA (this was in response to a drought which prevented normal levels of hydro-based electricity generation). The fall in oil prices in 2009 significantly reduced Fiji's import bill, as shown in figure 1.3.3b and table 1.3.3a.

Figure 1.3.3b Retained Fuel Imports in Fiji, 2000 - 2010



Source: Fiji Islands Bureau of Statistics, *Merchandise Trade Statistics* (various years); Reserve Bank of Fiji, *Quarterly Review* (various years)

[21] Retained fuel import data are used instead of total fuel import data, given that a large portion of fuel imported to Fiji is subsequently re-exported to smaller Pacific island countries (much analysis of oil price volatility in the Pacific incorrectly uses total fuel imports data in relation to Fiji – see for example Davies and Sugden (2010)). Data on retained merchandise exports are used for the same reason.

Table 1.3.3a Retained Fuel Imports in Fiji, 2005 - 2010

	Retained fuel imports as a percentage of merchandise exports*	Retained fuel imports as a percentage of GDP
2000	23	7
2001	29	9
2002	29	7
2003	28	7
2004	43	10
2005	60	12
2006	88	16
2007	81	14
2008	85	17
2009	53	10
2010	73	14

*Excluding re-exports
Source: Fiji Islands Bureau of Statistics, *Merchandise Trade Statistics* (various years); Reserve Bank of Fiji, *Quarterly Review* (various years)

Inflation also rises as a result of oil price increases, as oil is an important component in many economic activities (including transportation of goods to Pacific island countries). In 2008, inflation among Pacific island countries increased from an average of 2.5 to 12 per cent per annum as a result of fuel and food price increases (Sugden 2009). The IMF (2011) notes that the "pass-through" of oil prices increases in the form of inflation was almost total in Pacific island countries, whereas "pass-through" of food price increases was mitigated due to reductions in tariffs and the introduction of price controls in some countries. In Fiji, inflation rose from an average of 2.82 per cent between 2001-05 to 6.6 and 6.8 per cent respectively in 2008 and 2009 (Reserve Bank of Fiji various years).

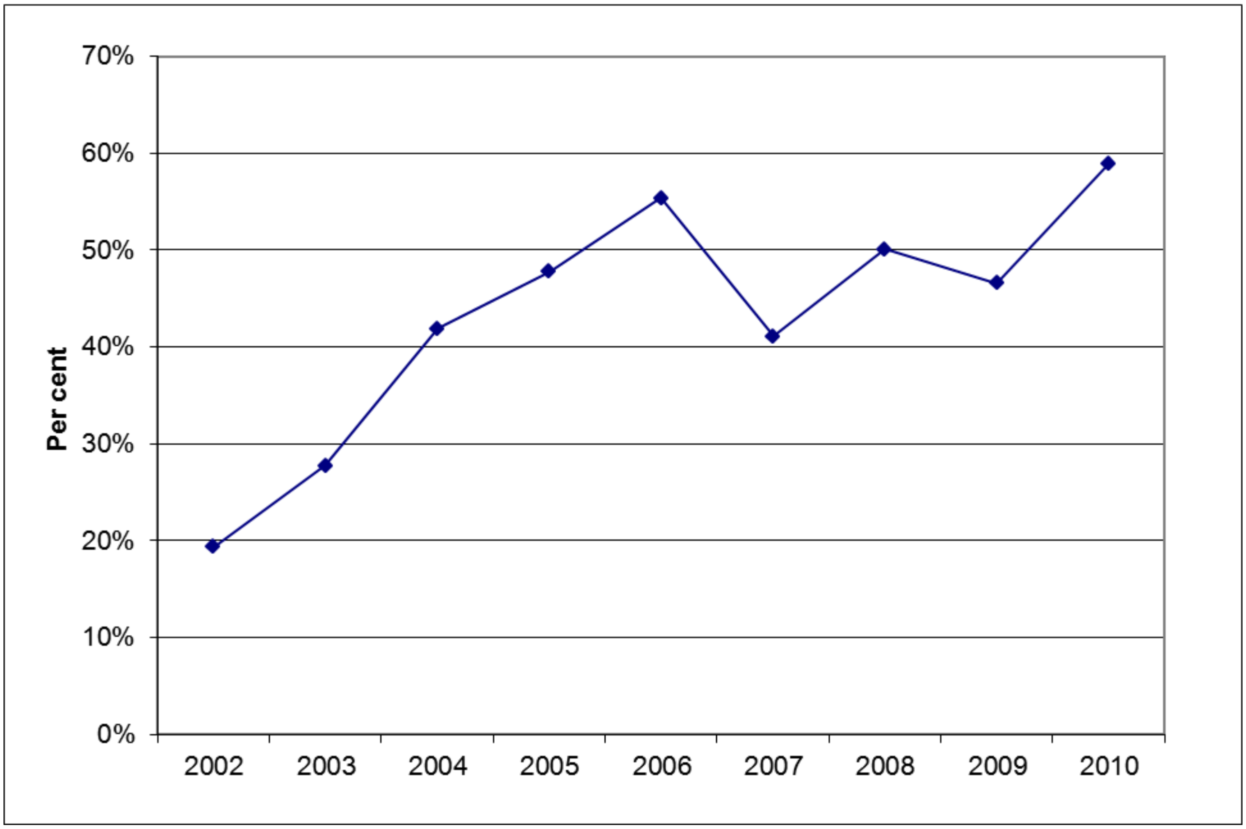
High fuel prices also have an impact on income. At a macroeconomic level, high import bills reduce Gross National Income. In Fiji, fuel imports as a percentage of GDP rose from 7 to 17 percent of GDP between 2002 and 2008 (see table 1.3.3a). This impact was equivalent to a reduction in Gross National Income of approximately 9 per cent.[22] At a household level, real incomes decline as a result of increased spending on fuel and due to inflation caused by oil price increases. Survey data presented in chapter five shows that the impact of high fuel prices in 2008 was particularly significant among rural households.

In the electricity sector, high oil prices increase power generation costs. The FEA is the largest consumer of retained fuel imports in Fiji (SMEC 2009). Oil consumption varies significantly from year to year, given the impact of rainfall patterns on hydro-based generation (the preferred generation method of the FEA). Nonetheless, oil price volatility has affected FEA finances. FEA spending on fuel as a proportion of its total operating costs increased from less than 20 per cent in 2002 to almost 60 per cent in 2010 (figure 1.3.3c). This is the result of both oil price increases and greater consumption of oil due to increases in demand for power (an issue discussed in chapter three).[23]

[22] This calculation is based on World Bank estimates of per capita Gross National Income (GNI) in Fiji of US$3,580 (using the ATLAS method) (World Bank 2011). These estimates are modestly higher than per capita GDP of US$3,168. If Purchasing Power of Parity calculations of GNI are used instead, per capita GNI in Fiji is significantly higher (US$4,490).

[23] Fortunately for the FEA, high levels of rainfall in 2008 allowed it to reduce fuel consumption at a time when oil prices were high.

Figure 1.3.3c FEA Expenditure on Fuel as a Share of Total Operating Expenditure

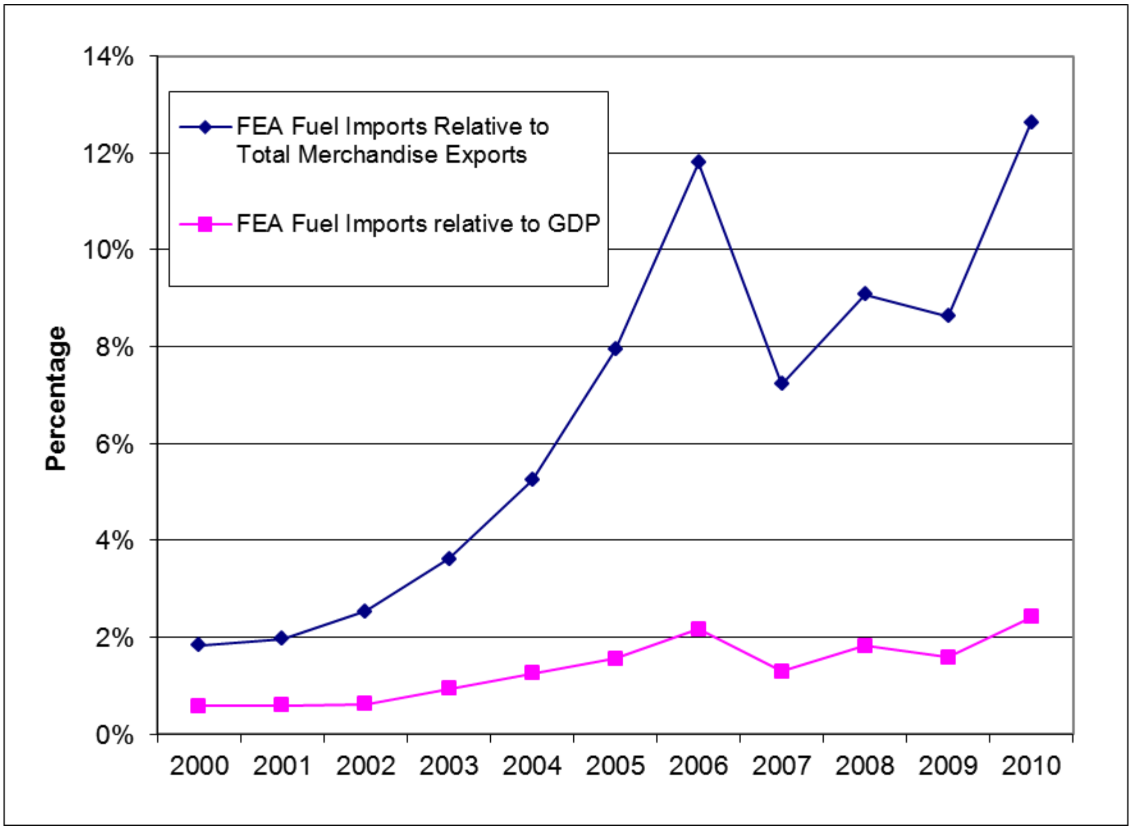


Source: FEA Annual Reports, various years

The increases in FEA expenditure on fuel demonstrate the importance of oil prices in the electricity sector. Expenditure on fuel for power generation also has macroeconomic implications. FEA spending on fuel in 2010 was equivalent to 12.6 per cent of merchandise exports, higher than revenue generated by any single merchandise export from Fiji (with the exception of fish), including sugar, gold, garments, and lumber exports (FEA 2010; Reserve Bank of Fiji 2011).[24] This is illustrated in figure 1.3.3d. Such data highlight the potential macroeconomic benefits from reducing oil-based power generation in the electricity sector.

[24] Exports of sugar collapsed in 2010, but 2009 figures were higher than FEA expenditure on fuel in 2010.

Figure 1.3.3d FEA Fuel Imports Relative to Merchandise Exports and GDP



Source: FEA Annual Reports, various years; Fiji Islands Bureau of Statistics, *Merchandise Trade Statistics* (various years); Reserve Bank of Fiji, *Quarterly Review* (various years)

1.4 The Dissertation

1.4.1 Objectives

This dissertation examines the impact of renewable technologies (including energy efficiency measures) on energy security in Fiji's electricity sector. The primary research question is: To what extent can renewable technologies improve energy security in Fiji's electricity sector?

Investment in renewable technologies has been advocated in Pacific island countries as a response to the threat posed by oil price volatility, with arguments in favour of renewable technologies commonly framed in terms of energy security. There has however, been little analysis of what is meant by the term "energy security", or how renewable technologies may contribute to energy security. There has been no rigorous analysis of the energy security impacts of investment in renewable technologies in Pacific island countries.[25] There has also been minimal research on the impact of institutional arrangements on energy security in the power sectors of Pacific island countries. These gaps in knowledge are addressed by this dissertation.

The dissertation focuses on the electricity sector, given the considerable scope for renewable-based power generation. Fiji was chosen as the case study, as it has a range of renewable energy resources and experience with renewable technologies in the power sector. Nonetheless, the approach employed in this research is applicable in other Pacific island countries and SIDS. Many of the general policy implications from the analysis are also relevant to these countries.

The research looks at both the electricity grid and rural areas not connected to the power grid (off-grid areas) in Fiji. The approach taken to assessing energy security in each case is different, given the importance of price and supply-based threats to energy security (explained in chapter two). Institutional arrangements for electricity provision are analysed in terms of their impact on investment and energy security in the electricity sector. Institutional arrangements are examined using the Institutional Analysis and Development framework (see Ostrom 2005).

1.4.2 Thesis Structure

This chapter has established the context for the research project and its objectives. The chapters that follow are described below.

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[25] A Master's thesis by Marconnet (2007) developed a mathematical model to look at the implications of renewable technologies for "reliability" of electricity supply in a number of Pacific island countries. This relates to the requirement in the case of a majority of renewable technologies for backup generation capacity, an issue also included in the modelling presented in chapter three. Marconnet did not look at the issue of generation costs and their relation to energy security.

Chapter 2 – Methods for Assessing Energy Security in Fiji's Electricity Sector

Chapter two details the conceptual frameworks used in this dissertation. The term "energy security" is explored with reference to the electricity sector in Fiji. Price and supply-based threats to energy security are distinguished. Price-based threats to energy security are most relevant in the electricity grid, whereas both price and supply-based threats are significant in rural off-grid areas. Methods for assessing threats to energy security in the electricity grid and rural off-grid areas are subsequently proposed. The chapter also notes the importance of institutional arrangements to energy security in the electricity sector, given their impact on power sector investment and (especially relevant in off-grid areas) maintenance. The Institutional Analysis and Development (IAD) framework is presented as a means of analysing institutional arrangements.

Chapter 3 – Fiji's Electricity Grid: Assessing the Economic Impact of Renewable Technologies

Chapter three assesses the energy security implications of investment in different renewable technologies for Fiji's electricity grid. A stochastic simulation model of electricity generation in the Fiji grid, based on portfolio theory, is developed and used for this purpose. The model assesses the implications of investments in renewable technologies on expected average generation costs and financial risk in the electricity grid. Power generation from renewable technologies is treated as variable in the model, thereby simulating actual variation in renewable-based power generation in Fiji. This is important in ensuring that the model accounts for short-term reliability of supply concerns of the power utility; which are especially significant in an isolated island-based electricity grid (Marconnet 2007; Mayer 2000). The modelling uses extensive cost and output data from electricity generators in Fiji, collected as part of the fieldwork for this dissertation.

Chapter 4 – Institutional Arrangements for Grid-Based Electricity Generation

Chapter four assesses the impact of institutional arrangements on renewable technology investments in the electricity grid. The analysis builds on the modelling work in chapter three, by discussing whether renewable technology investments supported by the model can occur in practice under current regulatory arrangements. The IAD framework is used to structure this discussion. The chapter also examines the scope for regulatory reform in Fiji, given international experience with power sector reform and past reform of state-owned enterprises in Fiji. The implications of power sector reforms recently announced (but not yet implemented) by the interim military government in Fiji are also discussed.

Chapter 5 – Rural Electrification in Fiji

Chapter five explores rural electrification and energy security in rural off-grid areas of Fiji. The state of rural electrification and rural electrification policy is analysed, with a focus on the performance of off-grid electrification technologies. Energy consumption, expenditure and the impact of high fuel prices on rural households is also explored, given that fuels such as kerosene are commonly used as substitutes for electricity in the provision of energy services. Analysis is based on fieldwork data collected through a survey, interviews and focus group discussion; supplemented by information from the Fiji Department of Energy and various reports (a partial list of people interviewed for this research is provided in appendix A1.1).

Chapter 6 – Analysis of Institutional Arrangements for Rural Electrification

Institutional arrangements for rural electrification are analysed in chapter six in order to explain fieldwork results. The IAD framework again structures this discussion. For solar-based rural electrification, maintenance issues identified by fieldwork are explained by information asymmetries between stakeholders, which result in principal-agent, motivational, and ownership problems. For diesel-based rural electrification, the analysis instead focuses on institutional arrangements at the village level, which govern the collection of money for fuel purchases and provision of maintenance. At the policy level, the establishment and implementation of rural electrification policy is also examined.

Chapter 7 – Addressing Barriers to Renewable Technology Investment: Policy Options

Chapter seven explores policy implications arising from this research. The financial and risk mitigation benefits highlighted by the analysis support forecast investments in renewable technologies in the electricity grid. The modelling results also suggest however, that investments should be re-prioritised, with less focus on hydro-power. There is also scope for renewable technology investment additional to that forecast by the FEA. This chapter highlights barriers to such investment and proposes a number of policy responses. It also reviews electrification targets and urges reforms to rural electrification programs in order to help address problems identified in this dissertation.

Chapter 8 – Conclusion

The final chapter provides an overview of the research project. It summarises the key research findings and policy implications of this dissertation. The chapter also discusses the relevance of this research to other Pacific island countries and Small Island Developing States, and identifies areas for further research.

Chapter 2

Methods for Assessing Energy Security in Fiji's Electricity Sector

This chapter sets out the conceptual frameworks used in the thesis. It begins by examining the term "energy security" and debates over its meaning. The discussion distinguishes between price and supply-based threats to energy security, which affect rural and urban areas differently. Methods used in the dissertation for quantifying energy security are also presented. These include portfolio theory, which is used in later chapters to assess the cost and financial risk implications of investments in electricity generation technologies. Another survey-based method is proposed for assessing supply-based threats to energy security in rural off-grid areas. The chapter concludes by presenting the Institutional Analysis and Development (IAD) framework, which is used in the dissertation to explore institutional arrangements in Fiji's electricity sector.

2.1 Introduction

This chapter sets out the conceptual frameworks used in the thesis. It builds on the introductory chapter, which provided the context for electricity generation in Fiji and described the impact of oil price volatility in recent years. Chapter one outlined how renewable energy technologies have been advocated in Fiji in recent years on energy security grounds. Despite this, there have been few attempts to clarify what the term "energy security" refers to in a Fijian context, and no rigorous attempts to quantify energy security or assess the energy security impacts of renewable technologies. This chapter establishes approaches for addressing these gaps in knowledge. It explores the following questions:

- What is "energy security"?
- Can it be quantified, and if so, how? If not, in what ways can energy security be assessed?
- What are the threats to energy security in the context of Fiji's electricity sector?

In doing so, the chapter develops the conceptual basis for addressing the central subject of this thesis: the extent to which renewable energy technologies can improve energy security in Fiji's electricity sector.

The chapter has five main parts. Section 2.2 examines the term "energy security" and debates over its meaning. Section 2.3 introduces the framework used to assess energy security in Fiji's electricity sector. Threats to energy security are defined as being either (i) price-based, or (ii) supply-based, with the relative importance of these depending on the presence of effective energy markets. In Fiji, threats to the security of electricity supply are primarily price-based in the electricity grid, as tariffs generally follow generation costs. Threats to the security of electricity supply in rural off-grid areas are both price-based and supply-based. A lack of effective markets means that both maintenance issues and fuel price volatility adversely affect power generation in rural areas not connected to the grid.

Sections 2.4 and 2.5 introduce methods for quantifying energy security. Section 2.4 discusses portfolio theory, which can be used to assess risk in the electricity grid, where threats to energy security are primarily price-based. Portfolio theory is commonly used in financial markets to quantify the return and risk profile of share portfolios. It can be applied to the electricity sector in a similar way, with generation costs replacing returns in the analysis, and risk measured by past variations in generation costs.

Section 2.5 presents an alternative method for quantifying security of electricity supply in rural off-grid areas of Fiji. The portfolio approach is not suited to assessing supply-based threats to energy security, as it defines risk only in financial terms. The method proposed for rural off-grid areas measures the time that electricity is unavailable, using data from surveys, interviews, and focus group discussions.

Measurement alone is not a satisfactory assessment of energy security in either grid-connected or off-grid areas. The causes of energy insecurity and potential policy remedies are also explored by this research. Section 2.6 introduces the Institutional Analysis and Development (IAD) framework, which is used in later chapters to explore institutional arrangements in Fiji's electricity sector. Institutional arrangements are significant to energy security in two ways. First, institutional arrangements are important in determining whether threats to energy security are price or supply-based. In rural off-grid areas of Fiji, institutional arrangements for rural electrification, established in the absence of effective markets, are highly relevant to explaining power outages resulting from maintenance issues. Second, institutional arrangements affect investment decisions in the electricity sector, and establish barriers to the introduction of renewable technologies in Fiji's electricity grid.

2.2 Energy Security as a Concept

2.2.1 Interpretations of energy security

Most forms of modern economic activity depend on secure and affordable supplies of "modern energy", which refers to electricity and fossil fuels but not "traditional" forms of energy such as traditional biomass (Goldemberg, et al. 1987; WBCSD 2007). Because of its role in fuelling economic activity, modern energy can be understood as a pre-requisite for economic growth, sustainable development, and poverty alleviation (Goldemberg, et al. 1987; UNDESA 2005; UNDP 2004; UNDP 2007a). The Pacific Islands Forum Secretariat states that:

> Energy has a vital role in achieving economic growth and sustainable development in the Pacific region. It is a fundamental input to most economic and social activities and a prerequisite for development in other sectors such as education, health and communications (Pacific Islands Forum Secretariat no date).

Energy security is important because of the role that modern energy plays in facilitating economic activity (ESCAP 2008; Soddy 1926). Discourse on energy security has been dominated by discussion of oil and to a lesser extent gas, as a result of their relative scarcity (especially for oil) and the geographical location of reserves (Klare 2008; Toman 1991). The term energy security is nevertheless broader than oil and gas. There are also linkages between the security of different forms of energy, such as oil/gas and electricity. For example, gas supply shortages have impacted on electricity supplies in recent years in Europe (Ölz, et al. 2007). In the case of the Pacific islands, the dominance of oil-based power generation means that the security of oil supplies has a direct impact on the security of electricity provision.

The term "energy security" remains highly contested despite its widespread use. One group of analysts defines energy security along geopolitical or national security lines. Energy security for this group is a zero sum game, where states compete for scarce and diminishing energy resources (Klare 2008; Toman 1991). The focus of this mercantilist understanding of energy security is firmly on oil resources, although increasingly gas is also viewed as important. Michael Klare (2008) for example outlines the increasing control of oil reserves by state-owned oil companies. He argues that competition for oil reserves is intensifying between the United States and China, pointing to China's investment in oil production in Africa, and its establishment of naval bases along key shipping routes.

Another group of authors reject geopolitical interpretations of energy security, focusing instead on the role of markets in preventing energy shortages. This group argues that energy security has been redefined by expansion of international markets for energy, and that the term should refer to the *price* of energy and its implications for affordability (Helm 2002; Ocheltree no date; Toman 1991; Toman 2002). Michael Toman states that "significant shortages never will be seen in a well-functioning market, but price increases signalling increased resource scarcity can be. These price changes should be the focus of policy" (1991: 13). In other words, in areas where markets are developed, any scarcity of energy will impact on consumers through the price mechanism.

The key assumption in this understanding of energy security is that markets exist and are well functioning. This assumption will be explored in the Fijian context in section 2.3. At an international level, the trend away from mercantilist towards market-based interpretations of energy security has followed the development of international markets in oil. Prior to the oil shocks of the 1970s, oil was primarily traded between the subsidiaries of western oil companies with concessions in oil exporting countries. Today, over 50 per cent of oil is traded on the open market.[26] The establishment of oil futures markets has also lessened dependence on long-term bilateral oil contracts (Goldhau and Witte 2009; Parra 2004). Goldhau and Witte (2009: 5) argue that, as a result, it does not make sense to talk about oil as a geopolitical commodity, because "once oil is sold on the global market, no producer can control where and to whom it goes." A counter argument is that markets are dependent on state support, which could be removed in the event of a crisis or conflict.

Conventional understandings of energy security, comprising a third group of authors, are influenced by both mercantilist and market-based viewpoints. The International Energy Agency (IEA) (IEA 2007b: 160) defines energy security as: "adequate, affordable and reliable supplies of energy". Its definition recognises the importance of energy affordability, but also stresses the physical supply of energy. This definition is dominant in western countries. In Australia for example, energy security is defined as "the adequate, reliable and affordable supply of energy to support the functioning of the economy and social development" (Australian Government 2009: 5).

These understandings of energy security are situated between mercantilist and market-based definitions of energy security. The IEA rejects the assumption of a zero sum game advocated under mercantilist interpretations of energy security, instead highlighting the need for international cooperation in ensuring supply security (IEA 2007a). It is nevertheless cognizant of the tensions caused by high energy prices. Similarly, the IEA stresses the importance of trade and energy markets in providing energy security, while noting that the provision of energy security is a public good which warrants government involvement.[27]

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[26] The rise of markets for oil was somewhat ironically the result of the nationalisation of oil production by oil exporting states. The nationalisation of oil production broke up the vertically integrated western oil companies, while also making the newly formed national oil companies reliant on western oil companies for refining capacity and retailing outlets. Oil came to be traded on markets as a result (Goldhau and Witte 2009).

[27] The IEA states that: "Markets alone do not reflect the cost to society of a supply failure…all market players benefit from action to safeguard energy security, whether or not they have contributed to it. For these reasons, governments must take ultimate responsibility for ensuring an adequate degree of security within the framework of open, competitive markets" (IEA 2007b: 161).

The IEA also draws a distinction between short-term and medium/long-term threats to energy security.[28] Short-term threats to energy security are associated with natural disasters or technical problems, and result in energy shortages in the short-term. Medium/long-term threats to energy security refer to situations where disruptions are ongoing, and are commonly associated with geopolitical issues, conflict, or lack of investment (IEA 2007a). Medium/long-term can result from a number of factors, such as disruptions to oil imports or lack of investment in power sector infrastructure (a problem in many developing countries, although not in Fiji) (Besant-Jones 2006; Choynowski 2004; Rosenzweig, et al. 2004).

The majority of research and policy analysis of energy security focuses on medium/long-term energy security. Medium/long-term threats to energy security, or situations where disruptions are ongoing, are also the focus of this thesis.

2.2.2 Implications for Policy and Measurement of Energy Security

The various interpretations of energy security have different implications for policy, and for measurement of energy security. A focus on national security is strongly associated with arguments for energy self-reliance. Relevant measures of energy security from this perspective include the percentage of energy resources that are imported, scarcity of domestic energy supplies, and the ability to protract military force in other countries to safeguard energy resources. A market-based interpretation of energy security results instead in a focus on ensuring that markets are in place and effective. This approach eschews the need for measurements such domestic resource scarcity or energy imports (Keller, et al. 2009).

The conventional interpretation of energy security used in this thesis cautiously adopts policy recommendations from both perspectives. It does not advocate self-reliance, but

[28] The IEA addresses both long-term and short-term threats in its activities. It requires member countries to stockpile energy supplies in order to address short-term energy supply shortages. At the same time, it seeks to improve energy security in the long term by promoting markets in energy, expanding investment in production capacity, and encouraging the diversification of energy supplies (IEA 1995; IEA 2007a).

does argue for the establishment of reserves to prevent short-term supply shocks, and for promotion of renewable energy technologies. Scarcity and energy imports are two factors among many that governments need to consider when formulating energy policy. Market effectiveness and the ability of low income households to afford energy are also important.

These comparisons demonstrate that measurement of energy security is inherently subjective. Choice of relevant indicators is based on a particular world view, and is often highly political. The same is true of the way in which energy security objectives are integrated with broader policy goals.

The 3A approach of the World Energy Council provides a framework for incorporating energy security concerns into broader energy policy. The 3A approach identifies three dimensions that should be considered in the preparation of energy policy: accessibility, availability and acceptability (World Energy Council 2008). *Accessibility* refers to "access to a minimum level of commercial energy services (in the form of electricity, stationary uses, and transport)" at "prices that are affordable and sustainable" (sustainable meaning that prices are sufficiently high to cover the production costs) (WEC 2008). *Availability* refers to the "continuity of supply in the long-term" and the "short term quality of service". *Acceptability* refers to ensuring that energy services are consistent with public attitudes, demands and concerns across a range of areas.

The three aspects of energy policy are not necessarily equal in importance. Frei (2004) uses Maslow's hierarchy of needs (1943) to argue for the prioritisation of some aspects of energy policy over others. Accessibility, he argues, is more important than whether supplies are secure (availability), while both accessibility and availability are considered more important than economic efficiency, environmental and social concerns (acceptability).

The definitions used by the World Energy Council (2008) and other authors are not always consistent. This is a problem in discussions regarding energy security, and reflects the fact that the concept is inherently subjective. The definition of energy security adopted in this thesis, “adequate, affordable, and reliable energy”, and its implications for measurement of energy security, is discussed next.

2.3 Frameworks for Assessing Energy Security in Fiji’s Electricity Sector

2.3.1 Price and Supply-Based Threats to Energy Security

Energy security in this thesis is understood as referring to “adequate, affordable and reliable supplies of energy”. The definition does not fit neatly into the World Energy Council’s 3A approach. The term “adequate” can be placed within all of the 3A’s, while “affordable” sits best within the first (accessibility), and “reliable” fits best in the second (available). In sum, the concept of energy security adopted here is broader than that used in the 3A approach.

The definition adopted here suggests that energy security can be threatened by both high prices, and physical cuts to the supply of energy. The extent to which threats to energy security are supply or price-based is dependent on the structure and presence of markets for energy. Threats to energy security are supply-based where markets for energy do not exist or are not effective. In these cases, the physical supply of energy is threatened where demand exceeds supply. The same does not occur where effective markets are in place, as higher prices serve to lower demand for energy and increase its supply, thereby avoiding physical shortages. Threats to energy security in this situation are instead price-based. Consumers are likely to reduce energy consumption as a result of high energy prices, with low income consumers the worst affected.

In both cases, energy insecurity can be understood in terms of a "loss of economic welfare" among consumers (Bohi and Toman 1996: 1). Energy insecurity experienced as cuts in supply results in reduced economic welfare, as consumers are unable to purchase energy. Energy insecurity experienced as increases in the price of energy likewise reduces the economic welfare of consumers, who must pay more for energy and may reduce consumption as a result. This framework is consistent with the approach pursued by the International Energy Agency, which argues that:

> Energy insecurity stems from the welfare impact of either the physical unavailability of energy, or prices that are not competitive or overly volatile… the relative importance of these depends on the market structure, and in particular the extent to which prices are set competitively or not (IEA 2007a).

A significant threat to energy security in the power grids of developing countries historically has been the failure to set electricity tariffs at levels that allow the utility to meet the cost of power generation. In many developing countries, electricity tariffs are consistently below the cost of providing that electricity, and governments must subsidise the state-owned electricity utility. This pricing policy has made power utilities and governments vulnerable to increased electricity generation costs (ADB 2008; Besant-Jones 2006; Rosenzweig, et al. 2004; UNDP 2007b; Weisser 2004b; World Bank 2006a). The impact of high generation costs in such situations is shifted onto taxpayers and away from electricity consumers.

Where subsidies are inadequate, the security of electricity supply is threatened. In some developing countries, oil price volatility in recent years has resulted in supply disruptions due to tariff inflexibility, in the form of rationing or blackouts/brownouts. In the Pacific, this problem affected countries such as the Solomon Islands and the Marshall Islands, with power utilities unable to purchase fuel for power generation due to financial constraints (which were exacerbated by poor performance in a range of areas) (ADB 2008; UNDP 2007b). In countries where electricity tariffs are flexible, threats to the security of power supply are instead primarily price-based. Electricity tariffs rise as generation costs increase, thereby threatening energy security through the price mechanism. The extent to which threats are supply or price-based is therefore dependent on the structure and presence of markets for electricity.

2.3.2 Threats to Energy Security in Fiji's Electricity Sector

The Fiji Electricity Authority (FEA) provides electricity to grid-connected areas of Fiji. Two sets of markets are important for the energy security of FEA-supplied electricity: factor markets for fuel, and product markets where electricity is sold. Aside from hydro-power, the main technology used to generate electricity by the FEA is oil-based generation, which uses diesel and heavy fuel oil sourced from international markets. International oil markets are generally considered to be effective, meaning that the price of oil rises when it is scarce, prompting supply from marginal (or high-cost) sources of oil and reducing demand. This minimises the prospect of supply shortages. When the price of oil rises, FEA generation costs also increase. The manner in which cost increases threaten the security of electricity supply then depends on whether electricity tariffs reflect generation costs.

It was noted above that in many Pacific island countries, electricity tariffs are lower than the cost of providing electricity. This has not been the case in Fiji, where throughout the 1990s, low generation costs from the Monasavu hydro scheme allowed the government to keep electricity tariffs low by Pacific island standards, with only minimal assistance to the FEA (World Bank 2006a). But higher demand for power in Fiji in recent years has resulted in higher generation costs for the FEA, with increased reliance on oil-based electricity generation and the need to invest in new generation capacity (Maunsell Limited 2005). The Commerce Commission has increased tariff rates since 2005 as a result, and has implemented fuel surcharges (or additional levies on electricity consumers) to assist the FEA in times of high oil prices (Commerce Commission 2009; Department of Energy 2006a). The threat posed by oil price volatility to security of electricity supplied through the grid in Fiji is therefore primarily price-based.

There are other financial threats to energy security that can affect the price of electricity. Changes in capital costs are most significant. These changes can result from unexpected cost increases for new projects, and/or from currency movements. The FEA has been affected in the past by currency movements. The 30 per cent devaluation of the Fiji dollar following the 1987 coup increased the FEA's debt from the Monasavu hydro-power scheme, which was denominated in foreign currency, by approximately FJ$99 million (the original cost was FJ$300 million) (Chaudhari 1995). Such risks can be hedged through financial instruments or by denominating debt in Fiji dollars, however this is not cost free (the FEA subsequently brought the debt onshore and converted it to long-term bonds that were protected from currency fluctuations). Currency movements can also increase project costs, as has occurred with the Nadarivatu hydro-power scheme currently under construction.

Reliability of supply is not a significant risk in the FEA grid. There is some potential for electricity supply shortages resulting from the high concentration of renewables in the electricity grid. In Fiji, this risk currently applies to hydro-power, which can be affected by drought. Other physical supply risks are less important. For example, there is some risk of short-term supply cuts resulting from natural disasters or technical problems. These do not impact on long-term security of supply. The threat of long-term power outages resulting from technical problems in the Fiji electricity grid is mitigated by ensuring that people with the appropriate expertise are employed to prevent and/or address technical problems (as occurs in the FEA).

The situation in rural off-grid areas of Fiji is very different from the electricity grid. Threats to security of electricity supply in off-grid areas are related to *both* price and reliability of supply. The price of diesel fuel is a cause of energy insecurity in rural communities reliant on diesel generators for their electricity. These communities are commonly cash poor, making them more vulnerable to price increases than urban communities.

Threats to the physical availability of electricity in rural off-grid areas are also significant. Supply-based threats to energy security include technical problems that require outside expertise to be fixed, and the unavailability of diesel fuel due to irregular shipping services (Bygrave 1998; Jafar 2000; Liebenthal, et al. 1994; Wade 2005b; Woodruff 2007). These threats have their origin in the fact that markets are not very effective. For example transport services in many off-grid areas are operated by government or private sector monopolies. Similarly, maintenance of power systems installed with government assistance is organised at the village level (for diesel-based generation), or as part of government-organised maintenance programs (for solar power systems). Such institutional arrangements have failed in many cases, as detailed in chapters five and six. Methods for assessing energy security will differ in off-grid and grid-connected areas of Fiji as a result.

The primary threats to security of electricity supply in both grid-connected and off-grid areas of Fiji are shown in table 2.3.2a. The table is based on an assessment of the literature and the author's analysis.

Table 2.3.2a. Significance of Threats to Energy Security in Fiji's Electricity Sector

Component of energy security	Threat to energy security	Fiji Electricity Grid	Off-grid Electricity Generation in Fiji
Price	Fuel cost	High for oil-based generation	High, where generation is oil-based
	Operation and maintenance costs	Minor	Medium – depending on fee-collecting institutions
	Capital costs (eg infrastructure costs)	Medium	Minor
Reliability of Supply	Fuel availability	Medium – high for hydro-power, low for oil-power.	High – where generation is oil-based
	Technical problems	Minor – for long-term energy security	High
	Natural disasters	Medium – mainly a short-term threat	Medium

2.4 Measuring Energy Security in the Electricity Grid: Portfolio Theory

The next two sections propose methods for quantifying the energy security implications of different generation technologies in Fiji. This section introduces an approach that is appropriate for Fiji's electricity grid, and closely resembles the portfolio theory approach traditionally used to assess risk in financial markets (Markowitz 1952). Its focus is on the price component of energy security, which as argued above, is the most significant threat to the long-term security of grid-supplied electricity in Fiji. The section that follows presents an alternative method of measuring threats to security of power supply, which is applied in rural off-grid areas.

2.4.1 Portfolio Theory: An Introduction

Portfolio theory provides a method for assessing the impact of renewable technologies on power generation costs and financial risk in the electricity sector. Mean-variance portfolio theory (referred to below simply as portfolio theory) was developed by Harry Markowitz as a method of valuing financial market securities based on the return and risk implications of each security for a portfolio of financial securities (Markowitz 1952). Under portfolio theory, the value of any security or investment has two components: its expected (mean) return and the risk associated with that return (being the risk that the actual return from the security will differ to its expected return). The risk of a security is defined as the standard deviation of past returns (Copeland, et al. 2005). Higher returns are generally associated with a higher level of risk.

Portfolio theory also considers the return and risk implications of a security in terms of its impact on the return and risk of an investor's *portfolio* of securities. In order to do this, the historical returns of that security must be correlated with those of the portfolio and their correlation coefficient estimated. Where the returns of the security in question are highly correlated with those of the portfolio, it will increase the risk of the portfolio. This is because at a time when the returns of the portfolio are low, the security in question is also likely to provide low returns. On the other hand, if the returns of the security in question are negatively correlated with the returns of the portfolio, its inclusion in the portfolio will reduce the total risk associated with the portfolio. This conclusion is intuitive. If a person has shares that are likely to fall in value in the event of a recession (eg, mining stocks), it would make sense to hedge this risk by purchasing shares that will not be negatively affected by a recession, or at least will be less affected (eg, a budget supermarket chain).

2.4.2 The Electricity Grid in Fiji: Applying Portfolio Theory

Portfolio theory can be applied to the electricity sector in much the same way as it is to financial securities, in order to assess the impact of generation technologies on an electricity grid's risk and expected generation costs. The type of risk that is incorporated in this type of analysis is financial risk, meaning the risk that actual generation costs will differ from expected generation costs in the future. Portfolio theory therefore provides a good measure of energy security in a context where markets are developed and the key threats to security of electricity supply are related to the price of electricity, provided this is determined in the long run by generation costs. This is currently the situation for the electricity grid in Fiji.

Portfolio theory was first applied to the electricity sector by Bar-Lev and Katz (1976), who used it to measure the benefits for utilities of diversifying their fuel suppliers. More recently, Shimon Awerbuch et al. have applied it to the valuation of electricity generation technologies (Awerbuch 2000; Awerbuch 2006; Awerbuch and Berger 2003; Awerbuch, et al. 2008; Awerbuch and Sauter 2006; Awerbuch and Yang 2008). Awerbuch (2000; 2006) is critical of existing "engineering-economic" methods used to value investment in electricity generation infrastructure, which are based primarily on the least-cost economic analysis of generation equipment performed on a stand-alone basis. These methods are biased against renewables, as they do not account for their unique energy security benefits (nor for their environmental or social benefits) (Awerbuch and Sauter 2006).[29] Instead, Awerbuch et al. propose using portfolio theory to value investment in generation technologies, as this approach incorporates:

[29] Awerbuch also argues that hedging does not offer a means of dealing with long-term energy security risk posed by oil price volatility due to the low liquidity of energy-sector hedging markets after one year (Awerbuch, 2000).

- a measure of risk, and
- the cost and risk implications of an investment on the entire portfolio of generation capacity.

Awerbuch et al. use portfolio theory to identify the cost and risk implications of investments in different generation technologies in several countries, including the United States, Scotland, and the European Union (Awerbuch and Berger 2003; Awerbuch, et al. 2008; Awerbuch and Yang 2008). Portfolio theory has since been used in other settings, including Australia (Vithayasrichareon, et al. 2010). It is increasingly used to measure the energy security implications of different generation portfolios (Bazilian and Roques (eds.) 2008; IEA 2007a). The focus of these studies is generally on measuring the energy security implications of renewable technologies.[30]

In applying portfolio theory to the electricity grid in Fiji, the expected future generation costs of each technology need to be estimated, and data on their past generation costs collected. Costs therefore replace returns as the primary indicator of interest when adapting portfolio theory for the electricity sector. Historical data are used to identify the variance of generation costs for each technology, and to correlate these with those of the generation portfolio. Where the cost streams of a technology have a high correlation with those of the generation portfolio, they will not improve energy security, as costs will move together with generation costs in the grid. This would be the case when adding gas to the existing power supply in Fiji, as gas prices are highly correlated with those of oil, which largely determine variances in grid-based generation costs. Incorporating gas into Fiji's electricity grid would therefore not significantly lower Fiji's vulnerability to oil price fluctuations.

The cost streams of most renewable technologies, on the other hand, are not correlated with those of oil-based electricity generation. The most significant cost associated with oil-based power generation is oil. The most significant cost associated with most renewable

[30] Portfolio analysis of the electricity sector has also been extended in several ways in order to better reflect the real world (see Bazilian and Roques (eds.) 2008 for a comprehensive overview). Notable contributions include applying portfolio theory to liberalised electricity markets where electricity suppliers do not share the same return and risk concerns as the grid (Roques, et al. 2008), and the incorporation of load factors into portfolio analysis in order to better value technologies based on whether they provide base, medium or peak load power (Gotham, et al. 2009).

technologies on the other hand is the capital cost of the technology (which is not influenced in a significant way by fluctuations in the price of oil and is determined at the time of investment). As such, renewable technologies can be expected to improve the security of electricity supply in the Fiji grid. Portfolio analysis can identify the extent to which they are likely to do so, and their impact on generation costs.

This idea can be illustrated using the simple equations below (the same procedure can be performed for portfolios with more than two securities, although the mathematics becomes more complicated) (Copeland, et al. 2005). Consider an electricity grid with a high risk but lower cost technology 1 (the equivalent of oil-based power generation in Fiji when oil prices are low), and a low risk but higher cost technology 2 (the equivalent of wind-power in Fiji). The expected portfolio cost, $E(c_p)$, is the weighted average of the expected cost of each generation technology, $E(c_i)$:

$$E(c_p) = X_1 E(c_1) + X_2 E(c_2)$$

Where X_1 and X_2 are the proportions of the total generation equipment made up of technology 1 and technology 2, and $E(c_1)$ and $E(c_2)$ are the expected (mean) generation cost of technologies 1 and 2. The risk of the generation portfolio, σ_p, is based in part on the weighted average of the risk associated with the cost streams of each individual technology, but is also determined by the correlation coefficient between the costs of the two technologies:

$$\sigma_\rho = \sqrt{X_1^2 \sigma_1^2 + X_2^2 \sigma_2^2 + 2 X_1 X_2 \rho_{12} \sigma_1 \sigma_2}$$

Where ρ_{12} is the correlation coefficient between the two cost streams and σ_1 and σ_2 are the standard deviations of costs of technologies 1 and 2.

Figure 2.4.2a Portfolio Effect for Two-Technology Portfolio

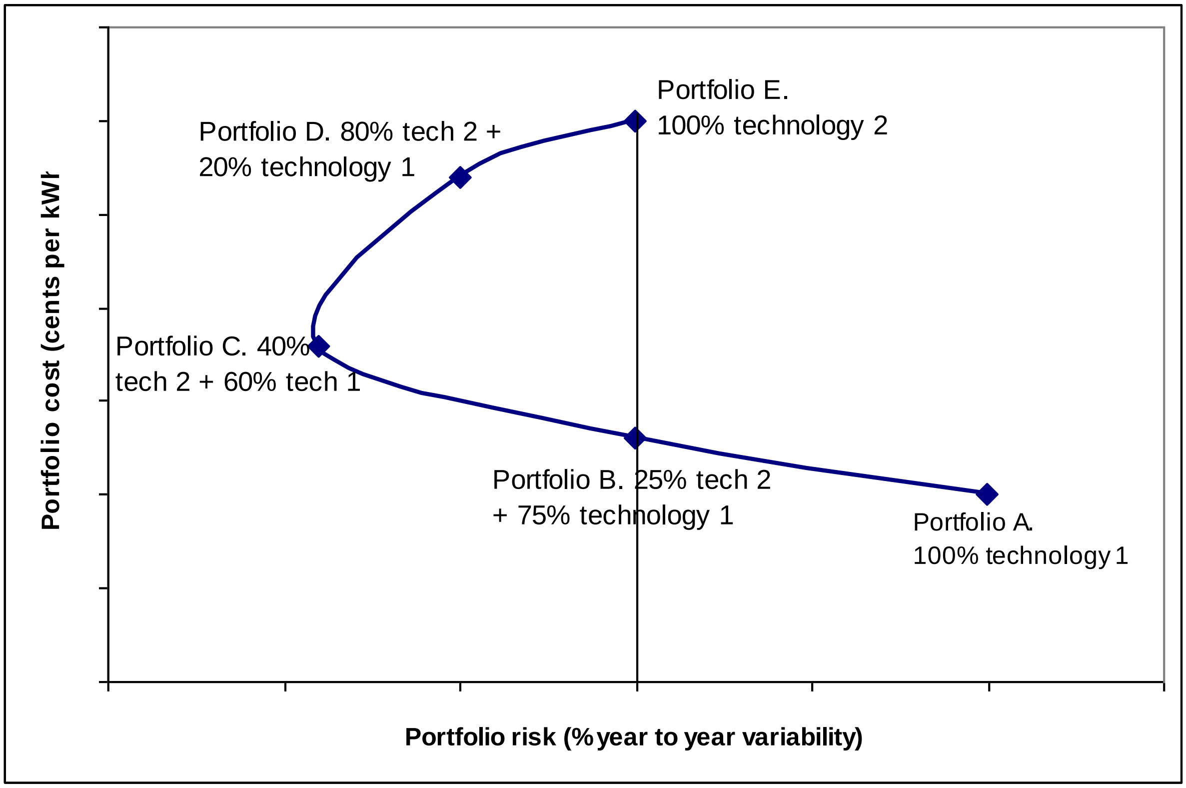


Figure 2.4.2a demonstrates the portfolio effect of changes in proportions of technologies 1 and 2 on power generation costs and financial risk. Because the cost streams of technology 1 and 2 are not perfectly correlated, investing in a portfolio that uses both technologies will reduce the total risk of the portfolio. A utility should aim to have the lowest possible generation costs for any given level of risk, and the lowest possible level of risk for any given cost. Where exactly it wishes to be on the efficiency frontier will depend on its aversion to risk. If it is more risk averse, it will want a portfolio similar to that at point C. If it is not risk averse and wants only to lower expected costs, it will want a portfolio like that at point A (comprising only the risky technology 1). The utility will not want a portfolio between C and E as at any point on this line both risk and costs are higher. Portfolio B is therefore superior to portfolio E: it has the same level of risk but a much lower cost.

A similar figure can be constructed for a portfolio with more than two technologies. In this more complex and realistic scenario, the utility could have a portfolio that lies below the efficiency frontier, say where risk is similar to that at point B but cost is greater, as is in fact likely to occur in the real world.[31] Portfolio theory can therefore provide guidance on possible investments in generation technologies that might lower portfolio generation costs with minimal effect on portfolio risk.

The application of portfolio analysis to Fiji's electricity sector is likely to produce results that are different from the example in figure 2.4.2a. This is because, as explained in chapter three, electricity production from renewable technologies in Fiji is generally both cheaper and involves less financial risk than oil-based generation. Put differently, the example above assumes a low-cost, high-risk technology (oil-based generation in Fiji) and a high-cost, low-risk technology (wind-based generation in Fiji). This assumption is based on the high-cost, low-risk nature of renewable technologies relative to coal or gas-based power generation in many parts of the world. The assumption does not hold in Fiji's power sector. Many renewable technology options in Fiji are both low-cost and low-risk relative to the oil-based electricity generation they would replace (wind-power is an exception). The portfolio effect of introducing renewable energy technologies into Fiji's electricity grid would therefore be expected to be different from that shown by research on other countries' grids. Investment in low-cost, low-risk renewable technologies would instead move the electricity sector to a lower-cost and lower-risk portfolio (or closer to the origin in figure 2.4.2a). This result is described in detail in chapter three.

2.4.3 Complicating Factors

There are complicating factors that need to be incorporated in the portfolio analysis in order for it to better reflect real world constraints. Standard portfolio theory does not account for the intermittency of many renewable energy technologies. For example, solar photovoltaic panels can provide power at night only using expensive battery-based energy storage, however demand for electricity is commonly at its peak in the early evening. Similarly, wind turbines do not generate electricity when there is no wind; but demand for power

[31] Awerbuch (2006) shows that in the European Union, Mexico and the United States generation portfolios are below the efficiency frontier, with Mexico being the country furthest from the frontier. He posits that developing countries generally tend to be further from the efficiency frontier than developed countries, although does not provide reasons for this.

continues regardless. These technologies can meet only a certain percentage of the total electricity supply without investment in costly “back-up” generation capacity that would provide electricity in the event that these renewables stopped producing electricity (Diesendorf 2007; Eaves and Eaves 2007; Gotham, et al. 2009; IEA 2007a; Ölz, et al. 2007). The percentage of “non-solid” renewable technologies that can be admitted into an isolated grid, such as those in Pacific island countries, without back-up capacity is lower than in grids that are interconnected (Marconnet 2007; Mayer 2000). In Fiji, back-up capacity would most likely comprise oil-based generation. Modelling of Fiji’s power grid needs to account for this by bundling certain renewable technology investments with investments in back-up capacity.

A second point is that there are limits to the availability of some forms of renewable energy resources. In Fiji for example, there are limits to the amount of bagasse produced from the sugar milling process that can be used to generate electricity. There is also seasonal variation in the availability of bagasse fuel. These limits need to be incorporated into the portfolio analysis.

The most important issue in the case of Fiji is the risk of drought affecting hydro-based power generation. Limits need to be placed on the amount of hydro-power that is allowed to supply the grid without back-up capacity. Incorporating this risk into portfolio analysis is not straightforward. The risk posed by drought is determined by a range of factors, including the capacity margin in the grid (the amount of spare capacity the grid has when demand is at its peak), the storage capacity of hydro-power sites, the location of hydro-power sites and whether these are in different catchment areas (and the correlation of rainfall patterns in these catchments), and the seasonal nature of rainfall.

Estimates of rainfall probability are also uncertain, based as they are on historical rainfall data. Future rainfall patterns are likely to differ as a result of climate change. The general consensus on future climate change in lower latitudes is that seasonal variation in rainfall will become more pronounced (Bates, et al. 2008; IPCC 2007). This is also predicted in Fiji, where rainfall in the wet season is predicted to increase, and rainfall in the dry season is predicted to fall (Australian Bureau of Meteorology and CSIRO 2011). The impact of such changes in Fiji on hydro-based generation is unclear. If annual rainfall remains constant but seasonal variations become more pronounced, power generation could potentially decline, given the low storage capacity of hydro-power schemes in Fiji. Furthermore, higher temperatures may lead to greater evaporation of stored water.

Chapter three outlines the approach for setting limits on renewable technologies that are incorporated in the portfolio model. These limits are determined by past variation of output from renewable-based electricity generation in Fiji. Specifically, the standard deviation of past monthly output is used to simulate output in a portfolio model (with an assumption that monthly output for each technology is normally distributed). Renewable technologies are admitted to the model in such a way as to ensure that there is less than a one per cent chance that the supply of electricity from a given generation portfolio will not meet demand for electricity. In other words, the generation technology portfolio must guarantee that 99 per cent of the time, sufficient electricity is generated to meet demand. This means that some investment in renewable technologies must also involve investment in back-up oil-based generation capacity. Due to the uncertainties described above, the model does not attempt to incorporate the impacts of climate change on hydro-power production. Chapter three presents the model and its findings.

2.5 Measuring Energy Security in Rural Off-Grid Areas

Quantitative analysis of threats to off-grid electricity supply can be used to assess the relative risk implications of different technologies. Portfolio theory is not suited to this task, as it measures only financial risk. Instead, a measure of risk is needed that incorporates both reliability of supply and price-based threats to energy security.

The only common measure of overall energy (in)security is the time that electricity is unavailable in an off-grid system. This information was gathered as part of this research project through surveys, interviews and focus group discussions, as detailed in chapter five. Survey respondents were asked about the number of hours/days electricity was unavailable in a given period, and the cause (and length) of each power outage. These causes included technical, and transport/logistical issues. In order to include the price aspect of energy security, rural electricity users relying on diesel systems were also asked if the price of diesel fuel had made it unaffordable, resulting in power outages. This is only a partial measure of the welfare effects of higher diesel fuel prices, as it does not incorporate situations where rural users actually paid for the more expensive diesel fuel. That was assessed by surveying the cost of fuel in rural areas over time and estimating its impact on households.

Survey results gave an indication of the relative importance of each threat to energy security. The results from communities using different electrification technologies were also compared. However, the approach on its own does not provide a comprehensive method for assessing energy security. The partial nature of measuring price-based threats to energy security has already been mentioned. Another problem with the approach is that data rely on perspectives (gathered through surveys and/or interviews), not fact. Problems relating to survey inaccuracies were addressed where possible through careful survey design, eliciting information in various ways to ensure internal consistency of results. A third issue is that survey results and some of the terminology can be difficult to interpret. For example, a statement like, “the price of diesel made it unaffordable”, is not equivalent to a measure of price variability. It could instead relate to the lack of cash income in rural areas.

Lastly, the diversity of surveyed communities means that general conclusions about the energy security implications of each technology cannot be made in the same way that they can for the electricity grid. Threats to energy security are specific to rural communities, which differ in their geography, ethnicity, culture, social organisation, income levels, resource endowment, and livelihoods. These features are both important and relevant to security of electricity supply. For example, cultural and social features influence preferences in the community and can determine the success of institutional structures for fee collection and/or maintenance. In Fiji, these differences are most pronounced when comparing indigenous Fijian villages with Indo-Fijian settlements. The results of quantitative assessments that rely on a limited survey sample therefore need to be interpreted with care. This last point stresses the importance of combining quantitative analysis of energy security with qualitative methods that are better equipped to deal with the diversity of rural communities. The Institutional Analysis and Development framework, presented in section 2.6, provides the structure for qualitative discussion in this dissertation.

2.6 The Institutional Analysis and Development Framework

2.6.1 The Need for Institutional Analysis

Analysis of institutional arrangements in the electricity sector is needed in order to understand the causes of energy insecurity and propose policy remedies. Institutional arrangements are important in several ways. First, institutional arrangements affect the nature of threats to energy security. In the electricity grid, threats to energy security are price-based, owing to the presence of effective markets and prices that reflect generation costs. In rural off-grid areas, threats to energy security are both price and supply-based. Institutional arrangements for rural electrification have been developed in the absence of effective markets. However, these have in many cases failed to adequately provide maintenance to installed systems, resulting in insecurity of electricity supply. Why have institutional arrangements for rural electrification failed to establish adequate maintenance programs? What are the barriers to ensuring security of electricity supply in rural areas? What are the potential policy remedies?

Institutional arrangements also matter because they frame investment decisions in the electricity sector. In the electricity grid, institutional arrangements determine the incentives of the FEA and other key stakeholders. What are the objectives of the FEA? What risks do decision makers take into account when making investments? What constraints do the FEA and other electricity producers face when investing in renewable energy technologies? These questions require an analysis of institutional arrangements in the electricity sector. Similar questions can be posed for rural off-grid areas. Why do households choose one electrification technology over another? What risks are considered? What are the constraints to rural electrification?

2.6.2 An Overview of the IAD Framework

The Institutional Analysis and Development (IAD) framework is a conceptual framework for understanding and explaining human behaviour. It was developed by Elinor Ostrom and others at the Workshop in Political Theory and Policy Analysis at Indiana University, in an attempt to integrate research by political scientists, economists, anthropologists, sociologists and other scholars interested in explaining the way that people make choices and interact with one another (Kiser and Ostrom 1982; Ostrom 2005). It is closely related to the new institutional economics and the new economic sociology, both of which acknowledge the role of institutions and social interaction in influencing human activity (Coase 2000; Nee and Swedberg 2005; Swedberg 1990; Swedberg 2007; Williamson 2002).

The IAD framework regards institutional arrangements as central to establishing the incentives of individuals and explaining their behaviour. Douglass North defines institutions as:

> humanly devised constraints that structure political, economic and social interactions. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights) (North 1991: 97).

Institutions structure the incentives and choices that individuals face when interacting with one another. The focus of the IAD framework is on “rules-in-use” rather than institutions more broadly. Rules-in-use refer to “rules as they are understood, generally followed by participants, and enforced – rather than…formal rules written in legislation, contracts or court decisions that may not be known to participants and affect their incentives and behavior” (Ostrom, et al. 2001: 5). Rules-in-use therefore refer to both informal constraints (norms) and formal rules, as they are understood and followed by individuals.

The IAD framework, in the tradition of the new institutional economics, assumes that individuals have "bounded rationality". In other words, individuals pursue multiple objectives for themselves (and others), using "imperfect information-processing capabilities", within an environment of incomplete knowledge (Ostrom 2005: 118). This is different to standard neoclassical economic assumptions of the rational individual. Indeed, an important function of institutions is to overcome uncertainty in a world of imperfect information. Incentives are also broadly defined in the IAD framework. This is appropriate for analysis in rural areas of Fiji, where social, cultural, and political incentives are commonly more important than economic incentives (as outlined in chapter six) (Curry 2003).

The IAD framework is described by Ostrom as "a universal framework … for explaining human behaviour" (Ostrom 2005: 7). A framework provides a means for organising an inquiry into a situation, and allows the researcher to identify which theories/models are relevant to a research question. It is broader and more general than a theory or model. A theory is used to explain phenomena in a way that is generalised beyond a given example, but cannot explain something as broad as human behaviour. Models are even more specific, and generate precise outcomes on the basis of a set of assumptions (Koontz 2003).

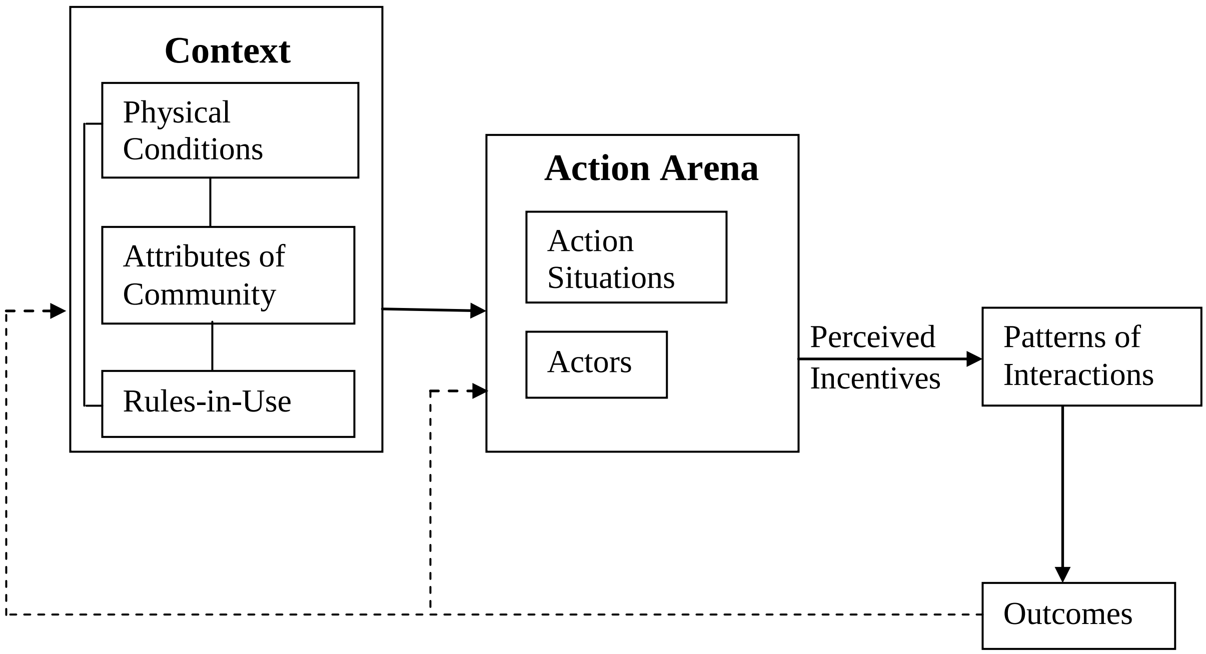
Different theories and models can be applied to different situations as part of the IAD framework. This enables the IAD framework to acknowledge and explain the diversity of social interaction. It also allows an analyst using the IAD framework to adopt theories and research from different disciplines, where these are relevant to explaining the interactions and choices of individuals.

The flexibility and interdisciplinary nature of the IAD framework make it an excellent conceptual tool for analysing institutional arrangements in Fiji's electricity sector. Electricity provision in Fiji is extremely diverse. It includes both large hydro-power projects operated by the FEA and small household solar power systems installed by the Department of Energy. The institutional arrangements that frame decisions about investment, operation and maintenance of these diverse systems are also very different. The FEA makes decisions in a complex regulatory environment, where issues of economic efficiency and governance structures are important. The power supply decisions of rural households require a different focus. Household decisions are framed by financial constraints and the rural electrification policies of the government, but are also strongly influenced by broader social relations within rural communities. Incentives (broadly defined) are important in both situations, but their analysis and evaluation requires the application of different theories from a number of disciplines. The IAD framework provides a means of framing that interdisciplinary analysis.

2.6.3 Applying the Institutional Analysis and Development Framework

The IAD framework has as its focus of analysis the "action arena", as illustrated in figure 2.6.3a. An action arena is where individuals and/or groups come together with different incentives in a series of interactions, which produce outcomes. The first step of analysis in the IAD framework is to determine the action arena that is relevant to the problem or issue being studied. In the case of energy security in rural areas, it might include operation and maintenance of a diesel generator. An action arena can be broken down into a series of action situations and actors. An action situation refers to a specific action/decision taken by an actor, which will have an impact on other actors. In the case of the diesel generator, one action situation might involve an individual contributing money for maintenance of the generator. The identification of an action situation in this way helps to focus the analysis on the decisions and corresponding incentives of individuals (Ostrom, et al. 2001).

Figure 2.6.3a The IAD Framework



Source: Ostrom et al. (2001: 23)

An action arena is always situated in a broader context. These are grouped for ease of identification in the IAD framework, and include physical/material conditions, attributes of the community, and rules-in-use (Ostrom 2005; Ostrom, et al. 2001). Physical/material conditions refer to the physical world in which an activity occurs. This includes geographical location, resource endowment, and status of technology. It also includes the nature of the goods being exchanged or produced. Electricity provided through the power grid is a private good that can be sold to customers by a utility. The same is not true for power provided through a village mini-grid diesel system, in which electricity is effectively non-excludable (meaning that households in the village receive electricity regardless of whether they pay for a generator's operation).[32] The non-excludability of power consumption in a village environment means that social relations between households in a village are important in determining arrangements for investment, operation and maintenance of the diesel generator.

[32] The supply of electricity from a mini-grid diesel generator is strictly speaking excludable, as households can be prevented from accessing power. However, social arrangements in the Fijian villages that were surveyed for this research made excluding a household not possible. Given these social norms, electricity supply in villages was effectively non-excludable; with power supply exhibiting features of a "common good". This is explained in chapter six.

Rules-in-use and the attributes of the community involved in the action arena are also important and are generally interlinked. Attributes of a community include: "the number of people involved, their homogeneity, the level and distribution of their assets, their history, etc" (Ostrom, et al. 2001: 25). Also important in a policy environment are the history of actors/organisations, their capacity, and assigned roles; as well as the history of regulation more broadly, including experience in other parts of the world. Attributes of a community have an impact on the development of rules-in-use. The level of trust between actors, for example, influences the rules-in-use that are required to carry out an activity (Ostrom 2005). In the case of diesel-based power generation in a rural Fijian village, the community is close-knit and there is a high level of trust between individuals. This makes organisation of power generation possible, despite its non-excludable characteristics. In this situation, only informal arrangements are required to ensure power generation.

The same trust does not exist between the thousands of individuals involved in the electricity grid. Formal rules-in-use are therefore established to ensure electricity is provided. Organisations such as the FEA are established as part of these rule-in-use, as they are a means of ensuring that workers are contractually obliged to perform given tasks. Regulatory arrangements are established to ensure that FEA management is accountable for the performance of the FEA across a number of objectives. Similarly, contractual arrangements frame relations between the FEA and other organisations and individuals (including customers). These are influenced by international arrangements for power sector regulation, and past experience in Fiji. The establishment of rules-in-use and the attributes of communities therefore overlap and are interlinked.

A key feature of the IAD framework is its understanding of human interaction as occurring at different levels. Rules-in-use that govern activity in one action arena are established in a higher-level action arena using another set of rules-in-use (Ostrom 2005; Ostrom, et al. 2001). In the electricity sector of Fiji, two levels of analysis are relevant to research on energy security. Investment, operation and maintenance in the electricity sector occur at the operational level of analysis. The rules-in-use that govern those activities are established at the policy level of analysis. For example, at the operational level of analysis, the FEA is the primary (although not sole) actor responsible for investment, operation and maintenance in the electricity grid. It conducts these activities in accordance with rules-in-use established by the Government of Fiji. Relevant rules-in-use include the regulatory regime for the electricity sector, as well as regulation of state-owned enterprises and the broader business environment (such as enforcement of property rights). These rules are established at the policy level of analysis.

In the chapters that follow, the IAD framework is applied at both the operational and policy levels of analysis when exploring institutional arrangements in Fiji's electricity sector.

2.7 Conclusion

This chapter has set out the conceptual frameworks for the thesis. It has explored the concept of energy security and discussed its relevance for the electricity sector in Fiji. An understanding of energy security as "adequate, affordable, and reliable supplies of energy" means that threats to energy security can take the form of both higher prices, and physical cuts to the supply of energy. The extent to which threats to energy security are supply or price-based depends on the structure and presence of markets for energy.

In Fiji's electricity grid, price-based threats to energy security are prevalent, and are likely to become more serious in the coming decades as oil prices increase and become more volatile (assuming continued reliance on oil-based generation). In rural off-grid areas of Fiji, threats to security of electricity supply are both price and supply-based. Higher fuel prices adversely affect power generation in communities that use diesel generators. At the same time, reliability of supply is an issue for off-grid electrification systems, with technical problems resulting from inadequate maintenance arrangements.

The chapter outlined two methods for measuring energy security. In the electricity grid where threats to energy security are primarily price-based, portfolio theory can be used to assess both the cost and financial risk implications of a given power generation technology. Chapter three applies this approach to Fiji's electricity grid. In rural areas, the same approach cannot be applied due to the importance of supply-based threats to energy security. An alternative method that measures risk on the basis of power outages is proposed, although its findings need to be interpreted with care and in conjunction with other survey and interview data.

Analysis of institutional arrangements in the electricity sector is also required if we are to explore threats to energy security and propose policy remedies. The Institutional Analysis and Development (IAD) framework provides a means of framing this discussion. Its flexibility allows for the application of different theories from a number of disciplines; which is important given the diverse nature of the electricity sector in Fiji. Chapters four and six adopt the IAD framework to analyse institutional arrangements in the electricity grid and in rural off-grid areas.

Chapter 3

Fiji's Electricity Grid: Assessing the Economic Impact of Renewable Technologies

There has been no rigorous assessment of the impact of renewable technologies on energy security in Fiji's electricity sector. This chapter addresses this knowledge gap by developing and applying a stochastic simulation model designed to assess the effect of renewable technologies on the financial risk and cost of electricity supply in Fiji. Empirical data on costs and output generally support investments in renewable technologies. Technology portfolios with investment in renewable technologies demonstrate lower generation costs and considerably greater energy security than portfolios without such investment. The modelling results indicate that investments in low-cost, low-risk technologies such as energy efficiency, geothermal, biomass and bagasse technologies are particularly beneficial. This suggests the Government of Fiji should be encouraging further investment in these technologies, commensurate with increases in total electricity supply. It also suggests that the FEA should consider such investments against planned expansion of hydro-power generation.

*The modelling in this chapter was done in collaboration with Dr Frank Jotzo

3.1 Introduction

The previous chapters described how renewable technologies have been advocated in Fiji's electricity sector in recent years on the basis of improving energy security and lowering power generation costs. These have been the primary reasons for the FEA's strategy of investment in renewable technologies, and its establishment of a renewable energy target. Despite this, there has been no rigorous quantitative assessment of the impact of renewable technologies on financial risk in Fiji's electricity sector. Such analysis is important if the effect of renewable technologies on Fiji's electricity sector is to be adequately evaluated.

This chapter addresses this knowledge gap by developing and applying a method for simultaneously assessing the contribution of renewable technologies to the security and cost of electricity supply in Fiji. Portfolio theory, introduced in chapter two, is applied in a custom-built stochastic simulation model to scenarios of future electricity generation, showing the impact of different renewable technologies on both expected generation costs and financial risk for the electricity grid. Several policy recommendations are made on the basis of the modelling results.

3.2 Grid-Based Electricity Supply in Fiji

3.2.1 Present Day Electricity Generation

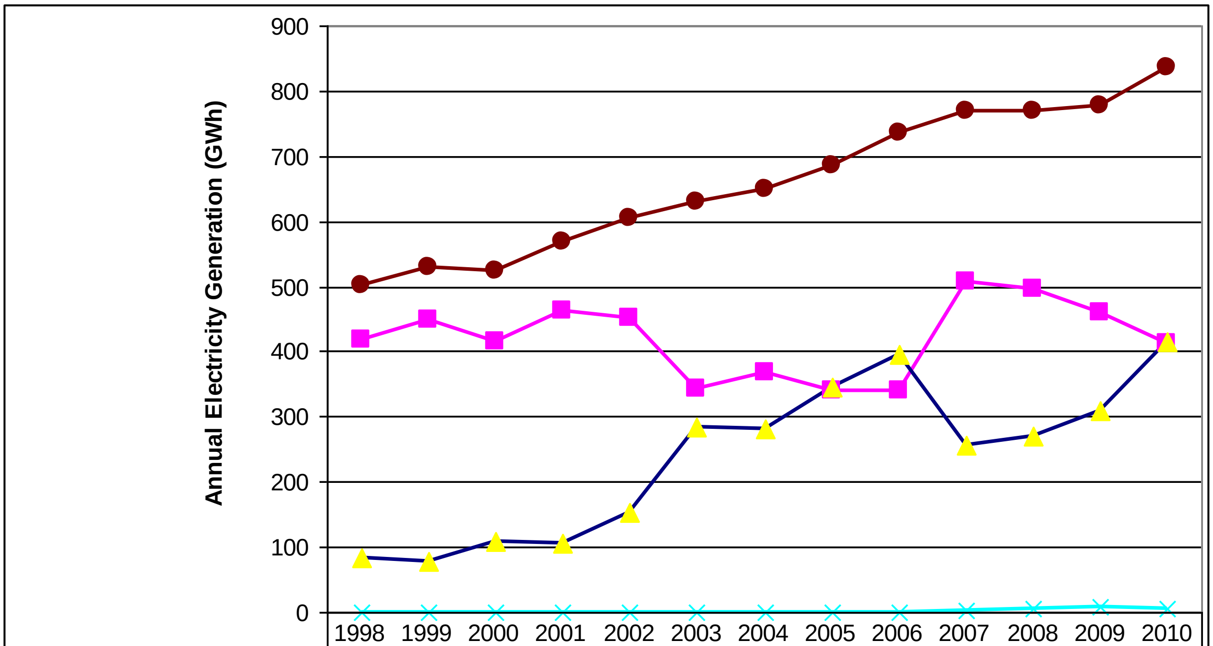
The FEA operates four electricity grids: one on the island of Viti Levu, two on the island of Vanua Levu (the Labasa and Savusavu grids), and one on the island of Ovalau. These locations were illustrated on the map in figure 1.2.2a. The combined power grids in Fiji have a peak load of 138 MW, and supply electricity to over 74 per cent of Fiji's population. The Viti Levu grid, known as the Viti Levu Interconnected System (VLIS), is by far the largest of these grids, representing over 94 per cent of FEA generation.[33] It also accounts for almost all electricity produced by renewable technologies, with most electricity generation in the three small grids produced using oil-based generators.[34]

The technological composition of electricity generation in Fiji has changed considerably over time. When the FEA was first established in 1966 it inherited mini-grids that were entirely dependent on electricity generation from fossil fuels (FEA 2009b; Interviews with Department of Energy, July 2009). In the decades that followed, the FEA expanded these electricity grids, eventually merging the separate grids in Viti Levu to form the VLIS. The ambitious Monasavu hydro-power scheme was completed between 1978-1982 with funding from the World Bank and various other donors. The hydro-power scheme at the

[33] Of the peak load, the VLIS accounts for approximately 126 MW, the Labasa grid for 6.5 MW, Savusavu for 1.9 MW, and Ovalau for 3.6 MW (Nittetsu Mining Consultants Co. Ltd. 2009).
[34] The exceptions are a small 0.8 MW hydro-power station at Wainiqeu that is capable of supplying about 2 GWh each year to the Savusavu grid, and the Labasa sugar mill that supplies small amounts of electricity to the Labasa grid in Vanua Levu.

time could meet all of Viti Levu's electricity needs and almost no oil-based electricity generation was required. Demand for electricity has since risen however, and cannot be met by electricity from the Monasavu scheme alone. Oil-based generation has therefore steadily increased as total demand rises, although there is variation in these figures from year to year, mainly as a result of variations in rainfall. This is shown in figure 3 2.1a.

Figure 3 2.1a. FEA* Electricity Generation by Technology, 1998-2010

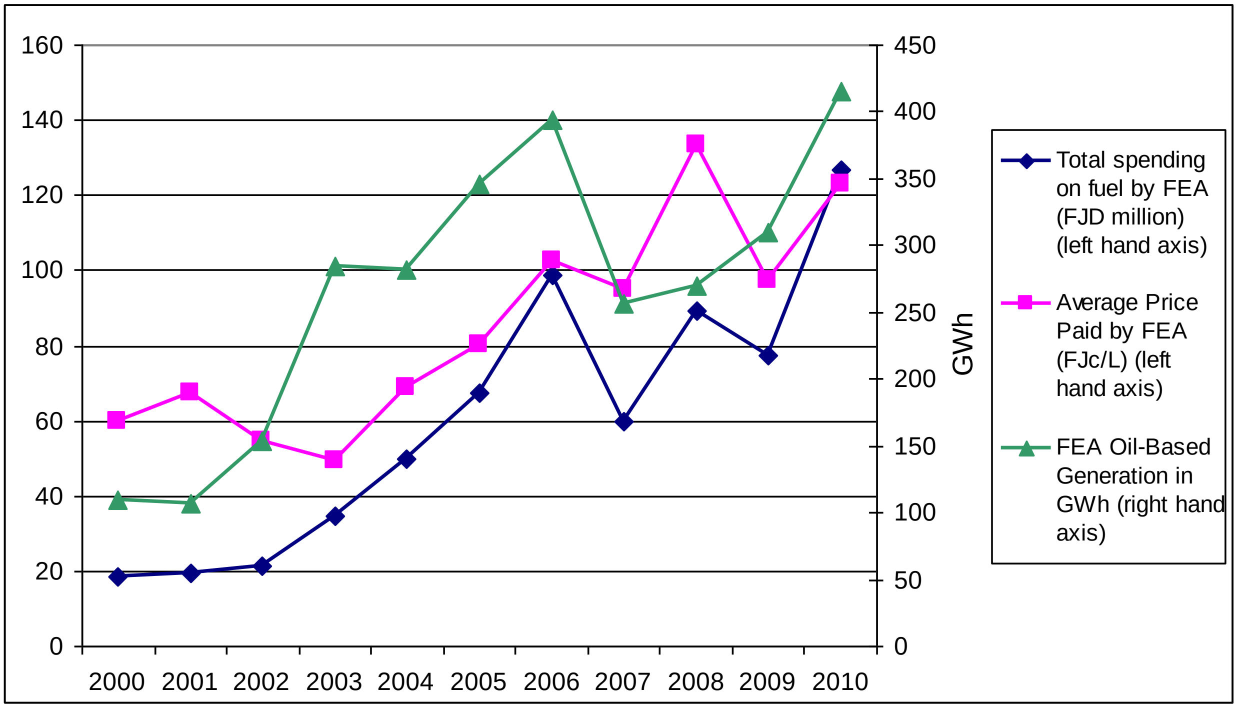


	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Hydro-based generation	418	450	414	463	450	344	367	339	341	508	495	460	414
Oil-based generation	85	79	110	107	154	285	282	346	394	256	270	310	415
Wind-based generation	0	0	0	0	0	0	0	0	0	3	5	7	6
Total generation	503	528	524	569	604	628	650	685	736	768	769	777	835

*The figure excludes generation by IPPs.
Source: Fiji Electricity Authority (FEA 2000; 2007a; FEA 2008a; FEA 2010)

Spending on fuel by the FEA has steadily increased over the last decade, although it has varied significantly on an annual basis, as shown in figure 3.2.1b. Increased reliance on oil-based generation is of concern, given forecast oil price increases and volatility (outlined in chapter two). Investment in cheaper generation technologies is therefore a priority for the FEA and the Government of Fiji.

Figure 3.2.1b. FEA Oil-Based Generation Costs, 2000-2010



Source: Fiji Electricity Authority (Annual Reports, 2000-2009)

The FEA has responded in several ways. It has converted some of its diesel plants to operate on heavy fuel oil (HFO), which is cheaper than the diesel fuel normally used.[35] It has also built two small 6 MW and 1.8 MW hydro-power stations, which supplied about 30 GWh of electricity in 2010, and a 10 MW wind farm. The FEA has also continued to purchase electricity from the Fiji Sugar Corporation (FSC) and has begun buying electricity from a 9.3 MW biomass plant operated by Tropik Wood. These measures have slowed but not stopped the growth of oil-based generation.

More recently, the FEA commissioned the construction of a 41 MW hydro-power plant in Nadarivatu, using a concessionary loan from the Chinese Development Bank. This is expected to generate about 101 GWh of electricity per year once completed in 2011-12, or a little more than one-fourth of power production at the Monasavu scheme. Oil-based generation should decline by about one-third of current levels as a result (FEA 2007b; FEA 2008a; FEA 2008b; FEA 2009a). A number of other projects are at a more preliminary stage. The FEA is planning to extend the Nadarivatu scheme by building a weir and power station at Qaliwana, which should provide 19.7 MW additional capacity and 43.8 GWh of

[35] It is also significantly worse for the environment (Interview with Anirudh Singh, July 2009).

power per year. It is also forecasting that by 2015, there will be new biomass-fuelled power stations operated by IPPs at Vuda and Labasa, additional generation capacity at FSC mills, and a geothermal power plant in Vanua Levu. These plans are detailed below.

3.2.2 Future Electricity Generation Options in Fiji

Hydro-based Generation

Hydro-power is currently the cheapest source of electricity available to the FEA (the capital cost of different hydro-power projects in Fiji is provided in Appendix A3.1). The Monasavu scheme produces most hydro-power in Fiji. It comprises the Wailoa hydro-power station and the Wainikaou hydro-power station, which were commissioned in 1983 and 2004 respectively. The Wailoa plant is the bigger power station, with four 20 MW penstocks that have a combined capacity of 72 MW and produced 413 GWh in 2010.[36] The 6.4 MW capacity Wainikasou hydro-power station is a recent addition to the Monasavu scheme and is situated upstream of the Wailoa plant. It produced 19 GWh of electricity in 2010. The Wainikasou plant uses water that later passes through the Wailoa plant, thereby increasing generation for any given level of rainfall (FEA 2003; FEA 2004; FEA 2008b).

Two other smaller hydro-power stations are also operated by the FEA. The larger one is in Nagado and uses water from the reservoir used to store Nadi's drinking water. The 2.8 MW plant was commissioned in 2006 and has since produced between 5 and 12 GWh each year.[37] The smallest plant is at Wainiqeu in Vanua Levu, and supplies about 2 GWh each year to the Savusavu grid. It is an older hydro-power station and has not been fully operational since 2002.

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[36] The 80MW Wailoa plant was downgraded to 72 MW after its construction due to design faults.
[37] The Nagado power station is constrained to 1.8 MW due to hydraulic vibration problems in it pipeline. The FEA expects that it will be able to produce 18 GWh of electricity per year in the future (Commerce Commission 2010c).

Where possible, the FEA uses hydro-based generation to provide base load power and reserves more expensive oil-based generation for peak load power.[38] The use of hydro-based generation for base load power by the FEA is restricted by water reserves that limit the amount of electricity that can be produced. These water levels are affected by rainfall patterns, which have considerable annual and seasonal variation.

Seasonal variation in hydro-power production is particularly high but follows a fairly reliable pattern, as shown in table 3.2.2a. At the Monasavu hydro-power scheme, water levels drop during the dry season from June to October each year as stored water is used to generate electricity. Water levels then increase rapidly during the wet season, especially during January to March when cyclonic activity occurs. In extremely dry years, water levels during the dry season can reach a critical point where the FEA has to stop generation at the Monasavu scheme altogether and rely instead on oil-based generation. These episodes are costly for the FEA and can also lead to rationing of electricity, as non-hydro capacity cannot meet peak loads.

Table 3.2.2a. FEA Monthly Hydro-Based Generation, 2005 – 2010* (GWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2010	43.6	37	38	33	35	32	25	23	25	24	48	50	413.6
2008	47	47	50	45	40	38	36.5	46.5	26.5	35	34	49.5	495
2007	50	43.5	50.5	48.5	48.5	39	30	23.5	31	49	45	50	508.5
2006	46.5	37	43	34	30	23	19	16	15	20	25	32.5	341
2005	22.5	22	27	26	39.5	26	20.5	21	26	27	34	47	338.5
Ave	41.92	37.3	41.7	37.3	38.6	31.6	26.2	26	24.7	31	37.2	45.8	419.3

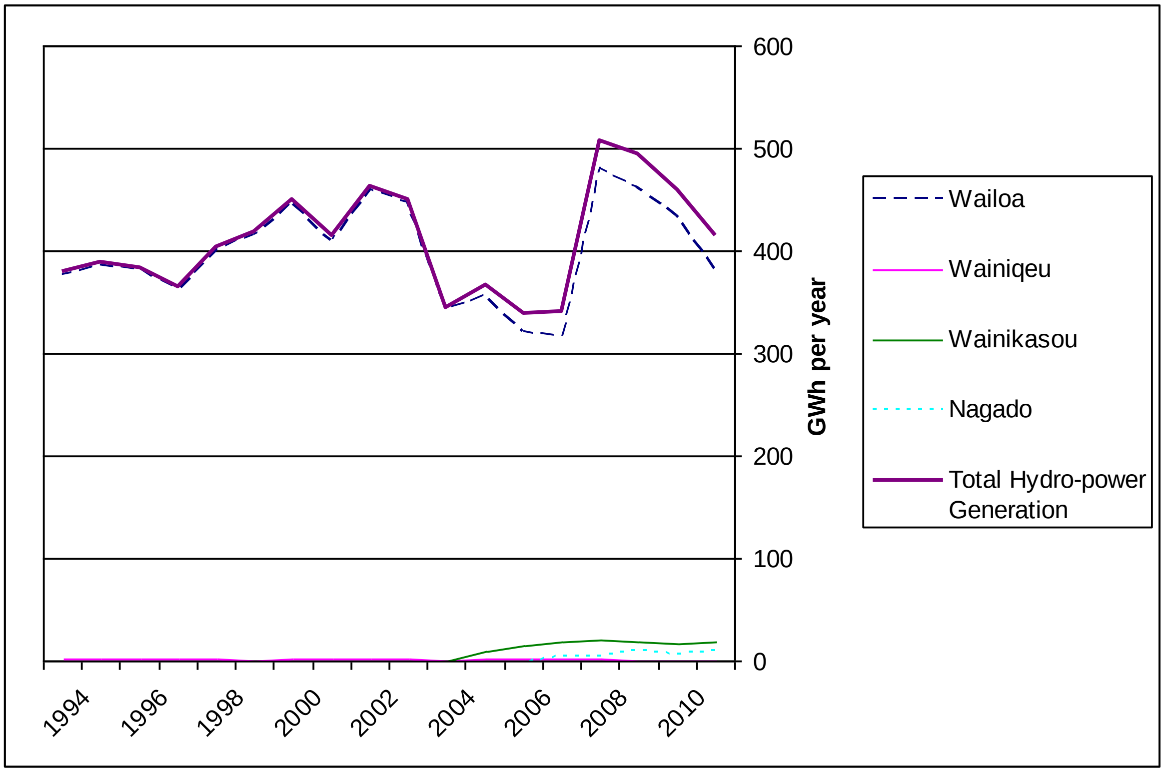
* The FEA has only made publicly available monthly generation data from 2004 – 2010. Data provided in the 2009 annual report for the year 2009, however was actually for 2008.

Source: FEA Annual Reports (2004; FEA 2005; FEA 2006; FEA 2007a; FEA 2008a; FEA 2009a)

[38] Peak load power refers to electricity supplied only at times when demand for electricity is highest. This typically occurs in the early hours of the evening when people return from work and are using lighting and other appliances. "Peaking" power plants generate electricity at peak times only, and are not operational during other periods. This means they may operate for only several hours each day. Base load power refers to electricity supplied at all times.

Electricity generation from hydro-power fluctuates considerably each year as a result of rainfall patterns, as shown in figure 3.2.2a. Two years in particular stand out: 2007, a very wet year, and 2006, a very dry year. These years recorded the highest and lowest levels of hydro-based generation respectively since the construction of the Monasavu hydro-power scheme.

Figure 3.2.2a. FEA Annual Hydro-based Generation, 1993 – 2009 (GWh)



Source: FEA Annual Reports, 2001 – 2009

Hydro-based electricity generation will increase in the near future with construction of a number of other new hydro-power schemes. These include the Nadarivatu and Qaliwana schemes; a hydro-power plant downstream of Wailoa (at the Monasavu scheme), which is expected to produce 35.6 GWh per year; and raising of the Wainisavulevu weir to allow for generation of an additional 7 GWh per year from the Monasavu scheme (Commerce Commission 2010c).

Reports commissioned by the Department of Energy (SMEC 2009; Vega 2001) estimate that there is the potential in Viti Levu for another three or four projects similar in size to the Nadarivatu hydro-power scheme, which together would generate approximately 300 to 400

GWh of electricity each year (the 400 GWh figure is used in this analysis). These projects would be small run-of-the-river schemes, like at Nadarivatu, and are therefore likely to have higher generation costs, and require relatively more back-up capacity than the existing Monasavu scheme, because of the limited capacity for water storage. The model presented below distinguishes between new and existing hydro-power in order to incorporate these differences.

Oil-based Generation

Oil-based electricity generation plays a special role in the FEA's generation mix. As the only non-renewable technology used by the FEA, oil-based generation is not affected by rainfall or wind patterns, or by changes in sugar or timber production. This means that it can be increased to fill the gap between demand and supply when there is reduced generation from hydro-power stations and other renewable technologies. Oil-based generation therefore ensures the reliability of electricity supply in the FEA grid by acting as a reserve margin. It can do this in a cost effective way compared to a situation where all power was provided by intermittent or seasonal renewable technologies. Coal and gas is not used to generate electricity in Fiji, and is not cost-competitive against the technologies listed here at the small-scale of the electricity sector in Fiji.

The biggest oil-based power generators are located in Kinoya (near Suva in the east), and Vuda (near Lautoka in the west), providing some measure of security if there were a cut in the important 132 kV transmission line linking the eastern and western parts of Viti Levu with each other and with the Monasavu hydro-power scheme.

Due to its high cost, oil-based generation in Fiji is used mainly to meet peak load requirements or when electricity generation from hydro-power stations is low due to poor rainfall. There is considerable variation in oil-based generation in Fiji as a result, both on a seasonal and annual basis. In effect, oil-based generation is the inverse of hydro-based generation: when one rises, the other falls. The model presented in this chapter incorporates oil-based generation in the same way, where it meets demand not met by renewable capacity.

There is not sufficient oil-based generation capacity installed in Fiji to meet peak load power requirements were there to be no production from renewable-based generation capacity. This can create problems when low rainfall limits the capacity to use hydro-power stations, and often leads the FEA to request that consumers limit power consumption, and hotels and other businesses operate their back-up generators (FEA 2000; FEA 2003; FEA 2008a; Islands Business 2008a; Mar 2002). In the last decade the FEA has experienced two electricity crises, in 2000 and 2003. The first saw landowners at the Monasavu scheme take advantage of the political instability generated by the 2000 coup and occupy the Wailoa power station from 6 July to 22 August, halting generation. Electricity was rationed among commercial customers as a result (Chaudhari 2001; FEA 2000). In 2003, voluntary rationing among commercial customers was put in place when low water levels reduced hydro-power generation (FEA 2003). Both episodes highlight the important role of oil-based generation in ensuring reliability of supply.

In recent years, the FEA has converted some of its diesel generators in Kinoya to operate on Heavy Fuel Oil (HFO), which is 15-20 per cent cheaper than diesel fuel (FEA 2008a). HFO fueled generators are used in preference to diesel generators wherever renewable technologies cannot meet demand. The current share of HFO and diesel-based generation capacity and generation is shown in table 3.2.2b.

Table 3.2.2b. Oil-Based Generation in Fiji, 2009*

	Capacity (MW)	Generation in 2009 (GWh)
Diesel Generation, VLIS	62.9	153.9
HFO Generation	20.0	112.26
Diesel Generation, Other	21.5	43.67
TOTAL	104.4	309.92

*Data on oil-based generation capacity are not available for 2010.
Source: (FEA 2009a; SMEC 2009)

The model presented below assumes present day shares of HFO and diesel-based power production continue into the future. There is no limit placed on potential oil-based generation in Fiji, as both generators and fuel can be purchased readily from overseas.

The Fiji Sugar Corporation (FSC) currently produces electricity from bagasse, a by-product of the sugar cane crushing process.[39] Electricity generation from the 31 MW capacity plant is seasonal, occurring during the dry season when crushing of sugar cane takes place. Electricity generation from bagasse is cheaper than oil-based generation in Fiji, although production can be affected by weather patterns and commonly stops during periods of rain (Interviews with FSC, August 2009). This means that electricity from existing biomass and bagasse plants cannot be relied upon as “solid” generation, and requires back-up oil-based generation capacity in the event that production ceases. The FSC currently operates a 12 MW and a 5 MW generator at the Lautoka sugar mill, and a 10 MW and a 4 MW generator at the Labasa mill. The former feed power into the VLIS, while the latter feed power into the Labasa grid in Vanua Levu (Interviews with FSC, August 2009).

The FSC has indicated that it could generate approximately 90 MW of power during the sugar cane crushing season if new generators are installed in its mills (SMEC 2009). This would equate to annual generation of 209 GWh based on current capacity factors (estimated generation potential for different technologies is shown in table 3.2.2c). For this to occur, the FSC would require new generation equipment for the Labasa and Lautoka mills (existing generation equipment is nearing the end of its economic life), and the introduction of generation equipment for the first time in the Rarawai sugar mill in Ba.[40] The use of new high pressure boiler technology currently used overseas would increase electricity production by 30 to 40 per cent for an increase in capital cost of only 5 per cent (Interview with FSC, August 2009).

[39] Strictly speaking, bagasse is a form of biomass. The fuels are referred to separately here given the unique features of the sugar industry in Fiji.
[40] The FSC has established a wholly owned subsidiary, Pacific Cogeneration Limited, in order to develop a 20-30 MW cogeneration plant at Rarawai mill in Ba, and at the Lautoka mill.

Table 3.2.2c Estimated Generation Potential for Technologies in Fiji

Technology	Generation Potential (GWh per year)
New hydro-power	501
Bagasse	209
Biomass 1 – Tropik Wood	73
Biomass 2 – Other IPPs	254
Geothermal	110

The FEA is forecasting annual electricity production from bagasse of 144 GWh by 2015, equivalent to approximately 56 MW of generation capacity. This includes the new power station at the Rarawai mill in Ba, and production all year from new generators in the Lautoka mill, which will operate on hog fuel from the timber industry when sugar cane is not being processed (Commerce Commission 2010c). There is a high likelihood that these plans will not proceed, given that they depend on the future performance of the FSC. The FSC is effectively bankrupt and has failed in recent years to improve the efficiency of its mills; an issue discussed in chapter four.

Biomass-based Generation

Electricity generation from biomass in Fiji is linked to the timber industry, and involves the burning of wood and associated waste. Generation costs from biomass are significantly lower than those of oil-based generators and also new hydro-power projects (when calculated using a 10 per cent discount rate) (see table 3.5.2a below). Biomass-based electricity generation is placed into two categories in the model presented below, on the basis of whether production is from a timber company or a dedicated power generation company.

Tropik Wood Industries Limited began generating electricity using biomass waste from timber production in May 2008 at its Drasa mill, in western Viti Levu. Tropik Wood is Fiji's largest timber company, and power generation is a small component of its overall business. Electricity generation by Tropik Wood (biomass 1) does not entail fuel wood grown specifically for power generation, and is largely about waste management. There are conflicting reports about potential electricity generation from Tropik Wood's 9.3 MW plant; technical problems make estimation of potential production difficult.[41]

The FEA had forecast annual power production by Tropik Wood of 24 GWh in a 2009 planning document, but later contradicted this estimate in a public document where it forecast annual production of 72 GWh from the same plant (Commerce Commission 2010c; SMEC 2009). Actual power production in the future will depend on mill processing by Tropik Wood. The higher figure seems exaggerated, as it assumes a capacity factor of over 88 per cent (the World Bank in comparison assumes 80 per cent capacity factor for purpose-built biomass-power generation plants). Production in the months when the generator has worked suggests annual electricity generation of only 18.9 GWh (or a capacity factor of 23 per cent). The model presented below adopts the 24 GWh figure originally forecast by the FEA in 2009 (which corresponds with a 29.5 per cent capacity factor).[42] This figure would be higher if Tropik Wood invested in additional generation capacity (see table 3.2.2c).

The second biomass category (biomass 2) includes a number of projects that are planned by IPPs which are new to Fiji. These companies have as their main purpose power generation, and plan to purchase or grow fuel wood. The two projects that are most advanced are the Vuda biomass project, construction for which is due to commence at the end of 2011, and the Labasa biomass project, which the FEA expects will commence full operations in 2014 (Commerce Commission 2010c).

The 17.8 MW Vuda biomass plant is the bigger of the two projects, and has been developed by a New Zealand-based IPP called Pacific Renewable Energy Limited (commonly referred to as Pac Energy). It will consume fuel wood grown by a separate company, which will be 80 per cent owned by Pac Energy and 20 per cent owned by landowners. Pac Energy expects generation costs of 23 FJc/kWh; slightly higher than the generation costs of Tropik Wood owing to the need to grow fuel wood. It forecasts annual power production of

[41] Tropik Wood's boiler suffered a major mechanical problem in April 2009 and was not repaired until October 2010, during which time no power was generated (FEA 2009a; FEA 2010; Interview with Tropik Wood, July 2009).
[42] This is much lower than is normally the case for purpose built biomass power generation plants, and can be explained by the fact that operation of the generator relies on wood processing at the Tropik Wood mill.

126.29 GWh with a capacity factor of 81 per cent (Pacific Renewable Energy Limited 2011). This is lower than FEA forecasts of 141.9 GWh (which would mean a 91 per cent capacity factor) (Commerce Commission 2010c). The Labasa biomass plant is still under development by Delta Energy. The FEA expects it will generate 31.5 GWh per year once fully operational, a significantly lower estimate than that of Delta Energy (Interview with Delta Energy, June 2011).

In the model, a capacity factor of 80 per cent is assumed for all new biomass projects, as this approximates the estimates of Pac Energy and Delta Energy and is consistent with World Bank assumptions about capacity factors for purpose-built biomass power generation facilities. The FEA forecasts that a further 10 MW of capacity will be constructed by 2018.

The model sets a maximum limit of 29.3 MW for biomass-based power generation from Tropik Wood, equating to annual production of approximately 73 GWh (see table 3.2.2c). This figure is based on previous investment plans by Tropik Wood for a 20 MW power production plant to supplement its existing 9.3 MW generator. A limit of 36.3 MW is established for biomass-based electricity production from IPPs, equating to annual power production of approximately 254 GWh (see table 3.2.2c). This upper limit is set on the basis that the biomass projects described above will consume a large portion of Fiji's biomass resources.[43]

Wind-based Generation

Fiji's only experience with grid-connected wind-based electricity generation is the Butoni wind farm, which was commissioned in July 2007. The 10 MW wind farm is located on the Butoni ridge near to Sigatoka town, in southwestern Viti Levu, and consists of 37 Vergnet GEV MP 275 kW turbines, which can be lowered and secured in order to protect them against cyclonic activity.

[43] As an example, Pac Energy assumes that between 10,000 and 20,000 hectares of fuel wood forest will be needed to fuel the Vuda biomass plant. This compares to total forest plantations of 150,000 hectares in Fiji (correspondence with Dr Hitofumi Abe, the SPC/JICA Regional Forestry Advisor, July 2011).

An important determinant of the levelised cost of wind-based electricity production is its capacity factor (or actual generation as a percentage of possible generation). This is determined in large part by local wind speeds. Power production from the 10 MW Butoni wind farm has been lower than anticipated as a result of poor wind speeds, with average annual production of 5.396 GWh per year (Tawake 2009). This makes electricity produced from wind-power in Fiji extremely expensive. Wind monitoring by the Department of Energy suggests that there are no locations near the electricity grid in Fiji where wind speeds are significantly higher than at Butoni. Future wind-based generation costs are therefore assumed in the model to be equivalent to those at the Butoni wind farm.

Solar-based Generation

Grid-connected solar-based power generation in Fiji has been very limited to date. Despite high solar insolation rates in Fiji, ranging from 4.5 to 5.7 kWh/m^2 per day (Vega 2001), the cost of solar-based power generation is likely to remain higher than that of other renewable technologies listed here (with the possible exception of wind-power). An estimated limit of 287 GWh from wind and solar is included in table 3.2.2c, given potential grid-integration issues. These limits are not reached in the modelling, as both technologies have relatively high generation costs.

Geothermal-based Generation

The cost of geothermal-based power generation is competitive with several other generation options in Fiji. Geothermal technology also has the advantage that it generates electricity at a near constant level; it does not suffer from the variability associated with wind or solar-based generation, or from seasonal variation that can affect bagasse, biomass or hydro-power production. Geothermal technology could therefore be used to provide base load electricity in Fiji.

Although there is currently no geothermal-based electricity generation in Fiji, there is evidence of geothermal resources in both Vanua Levu and Viti Levu. A preliminary feasibility study commissioned by the Japanese Ministry of Economy, Trade and Industry in March 2009 indicates that there is potential for 23 MW of geothermal-based electricity generation in Vanua Levu, at least 20 MW of which is near to the urban centres of Savusavu and Labasa (10 MW is near to each grid). Some of these resources could supply a 5 MW power plant, with the remainder being smaller (Nittetsu Mining Consultants Co. Ltd. 2009).

The FEA is forecasting approximately 4 MW of geothermal generation capacity will be installed by 2015 near Savusavu (Commerce Commission 2010c). This assumes that the now independent Savusavu and Labasa power grids are connected, as the combined grids have the requisite minimum base load demand of approximately 4 MW. The Savusavu grid by itself has minimum demand of only 1.3 MW, and would not support the geothermal capacity forecast by the FEA (Nittetsu Mining Consultants Co. Ltd. 2009; SMEC 2009). Delta Energy stated in interviews that it is negotiating with the FEA to connect these grids as part of its Power Purchase Agreement for the biomass plant at Labasa (Interview with Delta Energy, June 2011).

The model assumes an upper limit of geothermal-based generation of 15 MW in 2025, based on the pre-feasibility study conducted in 2009 (Nittetsu Mining Consultants Co. Ltd. 2009). This would involve 5-6 MW power stations placed at the two large deposits in Viti Levu (Tavua and Busa), in addition to the geothermal plant in Savusavu.

Potential Electricity Generation from Ethanol and Biodiesel

The oil-based generators that currently operate on Heavy Fuel Oil (HFO) are also able to operate on vegetable oil, including biodiesel. A report commissioned by the Department of Energy refers to a confidential World Bank study that analysed the economics of generating electricity using these fuels (SMEC 2009). The study found that generation from neither fuel was economically viable, although there were some social benefits in terms of raising rural incomes. Neither option is included in the analysis below.

3.3 Demand for Grid-Based Electricity in Fiji

3.3.1 Present Day Demand for Grid-Based Electricity in Fiji

Electricity use in the Fiji grid can be categorised into three main sectors:

- Electricity used in electrified households;
- Electricity used by the commercial sector (in shops, hotels, offices etc), or by government (in government offices, schools, hospitals, or for public lighting); and
- Electricity used for manufacturing, large-scale agriculture (sugar refining in Fiji) or mining.

The residential sector consumes approximately 30 per cent of electricity generated in Fiji each year (including but not limited to the FEA grid), the commercial and government sector consumes approximately 43 per cent, and manufacturing and large scale agriculture consume approximately 27 per cent (GWA 2011). The sectors most relevant when looking at electricity demand in Fiji's electricity grid are the residential and commercial/government sectors, as the third sector generates much of its own electricity.[44]

Electricity consumption in the residential, and commercial and government sector is divided by end use in table 3.3.1a. These figures are taken from a 2011 report commissioned by the Australian Department of Climate Change and Energy Efficiency and drafted by George Wilkenfeld and Associates Pty Ltd, *The Costs and Benefits of Introducing Standards and Labels for Electrical Appliances in Pacific Island Countries* (GWA 2011).[45] Refrigeration accounts for the most power consumption, followed by air conditioning and lighting. Other uses account for 22 per cent of power consumed in Fiji.

[44] Large-scale manufacturing, agricultural and mining enterprises generate their own electricity and in some cases feed surplus electricity back into the grid. This is done by the FSC, Tropik Wood, and the Vatakuola Gold Mine. These companies sometimes also supply local homes of workers with electricity where access to the grid is not available.

[45] Some of these figures are extrapolated from a 2006 study by the same author on the *Costs and Benefits of Energy Labelling and Minimum Performance Standards for Refrigerators and Freezers in Fiji* (GWA 2006). They are calculated from data on appliance ownership and estimating average use and electricity consumption for each appliance.

Table 3.3.1a. Electricity Consumption by End-Use in the Residential and Commercial and Government Sectors

End Use	Residential Sector (% total electricity consumption by end use)	Commercial and Government Sector (% total electricity consumption by end use)	Residential Sector and Commercial and Government Sector Combined (% total electricity consumption by end use)
Refrigeration	45	27	35
Air Conditioning	14	26	22
Lighting	18	25	21
Other	23	22	22
Total	100	100	100

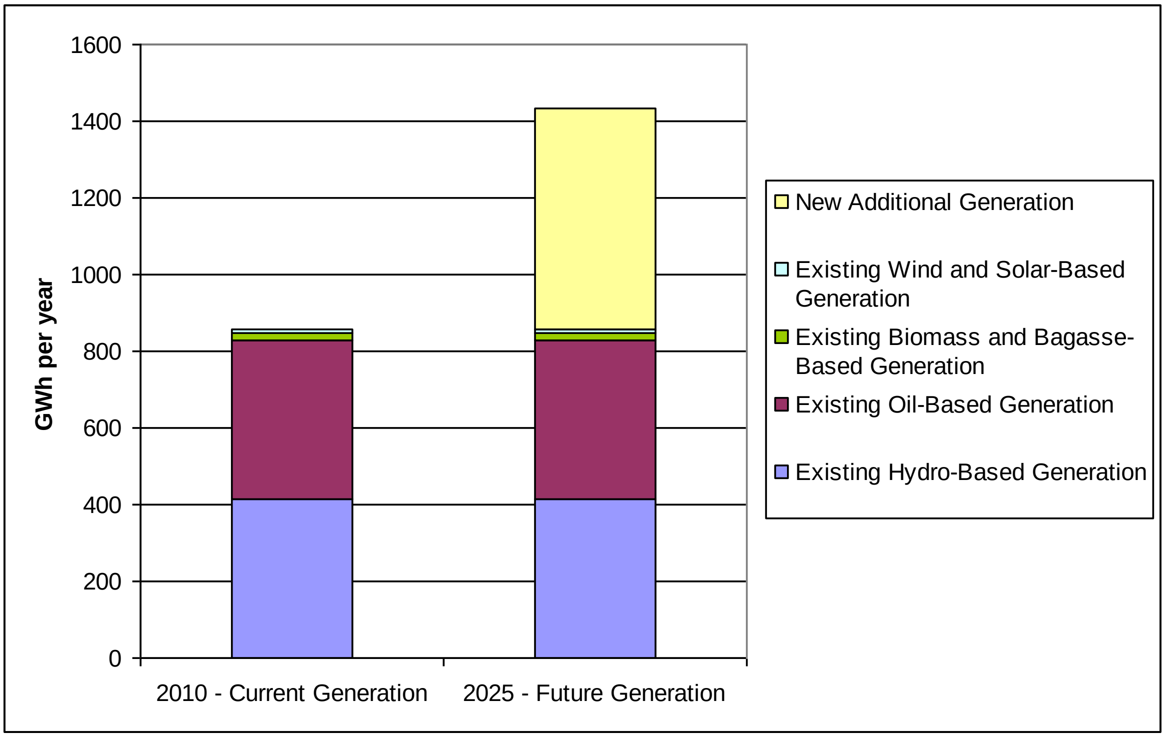
Source: George Wilkenfeld and Associates Pty Ltd (2011)

3.3.2 Future Demand for Grid-Based Electricity in Fiji

Forecast Grid-Based Electricity Demand in 2025

In 2010, a record 855 GWh of electricity was generated in Fiji's electricity grid. The FEA forecasts that electricity generation will reach 1435 GWh by 2025, a 68 per cent increase on current generation levels (SMEC 2009). This would entail an annual growth in electricity generation of 4.8 per cent from now until 2025. This growth is slightly lower than the average annual increase in generation of 5.6 per cent recorded between 1999 and 2010. Increasing electricity demand is the result of extension of the grid, electrification of new households, and higher demand for electricity among households already connected to the grid. The impact of this growth in demand is shown in figure 3.3.2a, which shows current generation by technology and the growth in required generation predicted by the FEA. Electricity supply increases significantly in these forecasts, reaching 168 per cent of current generation.

Figure 3.3.2a. Current and Future Electricity Generation in Fiji



The model developed in this chapter incorporates two alternate scenarios. In a “low growth scenario”, annual average growth in electricity demand is 3 per cent; while in a “high growth” scenario, annual average growth in demand is 7 per cent. These are discussed in more detail in section 3.6.

Reducing Future Demand for Power: Energy Efficiency Measures

There are a range of measures that have the potential to improve energy efficiency and reduce demand for electricity over time in Fiji. One involves upgrading of electrical appliances, such as refrigerators, air conditioners and light bulbs. Another set of measures involves improving the design of buildings so that they are more energy efficient. This could be very effective in reducing power consumption by air conditioners and lighting, which is particularly significant for the government and commercial sector.[46] A third set of measures involve FEA improving the efficiency of its generation equipment, and

[46] The Asian Development Bank notes that energy consumption by buildings is especially high in the Pacific; it estimates that in Vanuatu buildings 90 per cent of all electricity generated is consumed on activities related to buildings (such as air conditioning and lighting) (ADB 2011).

transmission and distribution network. A fourth set involves improving the energy efficiency of industry practices that use electricity. A fifth set of measures attempt to reduce peak demand for power by increasing its price in peak periods.

There is limited information available on the quantitative impact of measures that could improve energy efficiency in Fiji. It is assumed here that there are limited gains to be had from efficiency improvements in the FEA's generation equipment, and transmission and distribution network. The FEA benefits from efficiency improvements where savings are greater than expenditure, and so most "easy wins" in this area have already probably been achieved (chapter four notes significant improvements in the area since internal reform of the FEA commenced in 2001).

Potential efficiency gains from modified building codes are likely to be more significant. However no quantitative information on such savings could be found and so these savings were omitted from the model. There was also no estimate of the impact on demand of increasing the price of power during peak periods. This also was omitted from the model as a result.

There is potential for efficiency gains that would reduce power consumption in some industries. It was already noted that most industry in Fiji generates its own electricity; however this is not the case across all industries. An industry of note is water supply. The Water Authority of Fiji consumes large amounts of electricity in the treatment of water, but has high losses of water (50 per cent of total production, according to a 2011 benchmarking report) (Pacific Water and Wastes Association 2011). Improving the efficiency of the water reticulation system would therefore reduce electricity consumption in the grid. Unfortunately, there are no data on how much electricity is consumed by the water utility or the cost of improving the water reticulation system. These potential savings have therefore been excluded from the model.

There is more information available on savings from the upgrading of electrical appliances. In particular, there are estimates on energy savings which would result from two complementary measures that could be introduced in Fiji (as well as other Pacific island countries).[47] One is the mandatory labelling of appliances so that consumers know how much energy appliances consume. This would allow consumers to make informed choices when purchasing an appliance. The second measure that could be adopted is Minimum Energy Performance Standards (MEPS). MEPS involves the setting of a legally enforceable minimum level of energy efficiency that appliances must meet in order to be sold in the market. MEPS effectively forces suppliers to meet minimum energy efficiency standards, while energy labelling indirectly influences supplier behaviour through consumer purchasing patterns.

George Wilkenfeld and Associates Pty Ltd (2011) argues that MEPS is likely to be more effective in the Pacific islands than energy labelling, as there are a limited number of appliance models sold in many retail outlets, potentially forcing customers to purchase less efficient appliances. Experience also suggests that customers in the Pacific often choose less energy efficient appliances simply because of their lower upfront cost.

Energy labelling and MEPS are nevertheless complementary, with both approaches having been implemented in Australia and New Zealand. MEPS removes the least efficient appliances from the market, while labelling promotes more efficient models among the remaining appliances (GWA 2011). The implementation and administration of energy labelling and MEPS are also complementary. For either energy labelling or MEPS to be introduced, a compliance framework is required that measures the energy use of appliances and ensures that retailers and suppliers provide accurate information to the consumer, and market only appliances that meet minimum energy efficiency standards. The compliance systems for both energy labelling and MEPS use the same energy tests and information database on appliances. This means that once a labelling program is in place, the cost of implementing MEPS is marginal, and vice versa. In Fiji and other South Pacific island

[47] These are not the only measures that could be introduced in order to improve the efficiency of electrical appliances. A change in pricing structure, such as the introduction of higher prices during peak load periods, would also have an impact. Campaigns by the FEA to improve efficiency would also have an effect. The FEA could be provided with impetus for such campaigns if the tariff determination process were changed so that it had to justify new investments in generation capacity against investment in demand side management. This is discussed in more detail in chapters four and seven.

countries, standards from Australia and New Zealand could be adopted in order to minimise implementation costs.[48]

Estimates of the potential energy savings in Fiji from implementing Australian/New Zealand energy efficiency labelling and MEPS are provided in table 3.3.2a. These figures were calculated by George Wilkenfeld and Associates Pty Ltd (2011), which argues the primary reason for these savings is the removal of energy inefficient appliances currently exported to Pacific islands that are not compliant with MEPS elsewhere. Potential power savings in Fiji amount to 104 GWh in these estimates, forming the upper limit for energy efficiency savings assumed in scenarios in the modelling. A full description of the impact of energy efficiency measures on Fiji's power sector is provided in Appendix A3.2.

Table 3.3.2a. Electricity Savings from Energy Efficiency Measures in Fiji (by Sector and End Use)

	Savings in Fiji (GWh per year)	Savings (% of total energy efficiency savings)
Residential refrigerators	15.93	15.30
Residential freezers	4.95	4.76
Residential air conditioning	21.17	20.33
Residential lighting	15.08	14.48
Commercial/Government Refrigeration*	6.96	6.69
Commercial/ Government Air Conditioning	18.85	18.11
Commercial/ Government Lighting	21.17	20.33
TOTAL	104.11	100

*Includes both refrigerators and freezers.

Source: Adapted from George Wilkenfeld and Associates Pty Ltd (2011)

[48] The same is not true for Micronesian countries in the north Pacific, which use electricity voltage used in the United States. For these countries, energy efficiency standards could be modelled on those used in the United States.

3.4 Economic Evaluation of Electricity Sector Investments

The most common method used to evaluate competing investments in electricity generation technologies has traditionally been least-cost analysis. Chapter two described how this method has been criticised in recent years for not accounting for risk and failing to look at the portfolio effect of investments (Awerbuch 2000; Awerbuch 2006; Awerbuch and Sauter 2006). Portfolio analysis provides an alternative method of evaluating electricity sector investments, by assessing the impact of generation technologies on an electricity grid's financial risk and expected generation costs.

3.4.1 Levelised Cost of Generation

In applying portfolio theory to Fiji's electricity grid, costs replace returns as the primary indicator of interest. The reasons that returns are not used is that (i) we are interested in the economic impact of generation on Fiji as a country, not the financial impact on the FEA, and (ii) returns depend heavily on electricity sector tariffs, which are determined by political processes. The expected generation costs of each technology are taken forward to 2025, with the exception of existing hydro-power capacity which is assumed to remain constant until 2025.[49] Historical data from Fiji and elsewhere is used to identify the variance of generation costs for each technology. Total electricity production in 2025 is set according to FEA forecasts, which assume annual power generation of 1,435 GWh (except in cases of higher or lower demand). The levelised unit cost of electricity is used when referring to the generation cost of each technology. This refers to the present day cost of generating electricity over the life of the technology, and is expressed in Fiji cents (using 2009 $FJ) per kilowatt hour of electricity produced (or FJc/kWh). It is calculated by adding together the capital cost of the technology, fixed and variable operation and maintenance (O&M) costs, and fuel costs, where relevant.

[49] Existing costs are used, as the biggest component of hydro-power generation costs is the capital cost. Future cost reductions in large-scale hydro-power therefore do not apply to existing hydro-power capacity in Fiji.

(i) Capital cost of the technology

Annual capital costs are calculated by discounting future costs using the Capital Recovery Factor, which converts an initial investment cost into a stream of equal annual payments using a discount rate. The levelised capital cost recognises that the present value of a dollar is higher than its future value. Calculation of the annual capital cost and the capital recovery factor is shown in the formulas below.

a) *Annual Capital Cost = Initial Capital Cost • CRF*

b)

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where, i = the discount rate and n = the life of the technology expressed in years (Jeynes 1956).

The levelised capital cost of the technology is normally expressed in terms of dollars per kW of generation capacity ($/kW).

(ii) Fixed and variable O&M costs

Fixed O&M costs are fixed regardless of the level of electricity generation. Variable O&M costs depend on the level of generation.

(iii) Fuel costs (where relevant)

The fuel cost for each technology is also dependent on the level of electricity generation.

Costs used in this thesis represent busbar costs, which refer to generation costs and exclude all distribution and transmission costs.

Where energy efficiency measures are considered, the cost of avoided electricity generation is used in the analysis, expressed in terms of dollars per kilowatt hour avoided. A kilowatt hour of avoided generation (popularly referred to as a “negawatt”) is equivalent to 1.15

kWh of electricity generation by the FEA, as transmission and distribution losses mean the FEA must produce this amount for 1 kWh to be consumed in a household (GWA 2011).

3.4.2 Discount Rates

The analysis below uses a discount rate of 10 per cent, and performs a sensitivity analysis using a 5 per cent discount rate. The use of a 10 per cent figure is consistent with the calculations of electricity generation costs presented in a comprehensive World Bank review of the cost of electricity generation using different technologies, on which some of the data used in the analysis is based (World Bank 2006b). It is also consistent with previous studies of renewable technologies in the Pacific islands (Woodruff 2007).

The use of a 5 per cent discount rate provides a different perspective, reflecting a higher concern for the welfare of future generations. The 5 per cent discount rate can be understood as representing the perspective of the Government of Fiji, whereas the 10 per cent discount rate reflects the perspective of the investing bodies, including the FEA and other IPPs. The use of both discount rates is consistent with the practice of the IEA and OECD of adopting two discount rates that reflect social and commercial priorities (IEA 1991; IEA 2005). A more detailed discussion of discount rates is provided in Appendix A3.3.

3.5 Method: Applying Portfolio Theory to Fiji's Electricity Sector

3.5.1 Modelling

There are several complicating factors that need to be incorporated in the model in order for it to better reflect the real world. One of these is the limits to total capacity of different renewable energy generation technologies in Fiji, which were discussed in section 3.2.2. Another is the ability of various technologies to meet demand for power, which is not accounted for in standard portfolio analysis (Awerbuch and Berger 2003; Awerbuch, et al. 2008; Awerbuch and Yang 2008). An electricity utility needs to ensure that there is sufficient generation capacity that can be “switched on” to meet demand when needed (Awerbuch and Berger 2003; Copeland, et al. 2005). This is especially important in an isolated power grid, such as those that exist in Fiji (Marconnet 2007; Mayer 2000). Some renewable technologies are intermittent by nature, and require back-up generation capacity, which would provide electricity in the event that these renewables stopped providing electricity. In Fiji’s case, this back-up capacity consists of oil-based generation. The amount of oil-based generation that is required to ensure reliability of electricity supply, and the degree of reliability that is required, are therefore both very important to the analysis.

These complicating factors are incorporated into the model in two ways.

1. *The variability of electricity generation from renewable technologies is incorporated in the model.* This is done calculating the standard deviation of historical monthly electricity production from each technology. Power production from each technology is simulated in the model based on this variability of past output. Production from “new” and “old” hydro-power stations are treated separately, as the existing Monasavu scheme suffers less variability in electricity generation than will the Nadarivatu scheme (based on stream flow analysis from the FEA) due to its greater storage reservoir.[50] Power production from wind-power is also highly variable. Geothermal power production is stable and can be used to meet base load electricity demand (Nittetsu Mining Consultants Co. Ltd. 2009). Production from existing biomass and bagasse plants is included in the model as producing no electricity for six months of the year, and operating at near full capacity for the remaining six months of the year. This specification reflects the dry and wet seasons in Fiji and is consistent with current power production in these sectors. New biomass plants are assumed to operate all year, as is planned by the IPPs currently considering investments in Fiji.

[50] As highlighted previously, future hydro-power schemes are likely to be similar “run-of-the-river” schemes like Nadarivatu, with little storage potential. This means generation from these power stations will be more affected by rainfall variability.

2. *The model recognises the role of oil-based generation in providing security of supply to Fiji's electricity grid*.[51] The model represents oil-based generation as a flexible back-up (or residual) form of generation that meets demand not met by renewable technology capacity. In other words, electricity supply from oil-based generators must always equal total electricity demand minus total output from renewables (which is a variable figure based on installed capacity from each renewable, and a random load factor representing natural variability). This requires a specific amount of back-up oil-based generation capacity for each possible combination of other generation sources.

The exact amount of back-up oil-based generation capacity is computed endogenously in the model, based on output from renewable technology capacity. To determine oil-based generation capacity, a cut-off for system reliability is established: in the simulations, the model supplies the full amount of electricity demand in 99 per cent of cases based on hypothetical one month time periods (in other words, there is a 99 per cent probability that there is no shortfall in total electricity supply in any one month). So, using a greater share of "uncertain" renewable technologies (such as new hydro-power) in the overall renewable technology capacity will mean there is a greater amount of oil-based generation capacity. This in turn raises overall generation costs, as greater capital outlays are required even if the generation capacity is idle for much of the time.

[51] Note that the model does not consider the geographical location of generation capacity, nor additional investments in transmission and distribution lines required for grid stability.

In this way, the model represents the system-wide cost implications of each particular investment in renewable energy capacity. The model therefore includes:

1. Capacity of each renewable technology (assumed for each scenario).
2. Expected monthly output from renewable technology capacity, computed from random realisations of output by technology, normally distributed with variability based on standard deviations from historical output data (as described in chapter two).
3. Expected output from oil-based generation capacity, computed from random realisations of (2.), as the residual to meet fixed total electricity demand given stochastic output from renewable technology capacity.
4. Required capacity of oil-based generation technology to fulfil electricity demand in 99 per cent of cases, computed from random realisations of (3.).
5. Cost data on each technology.

The model is implemented for numerical simulations using a Monte Carlo sampling approach, in the Matlab software package. All stochastic variables are distributed normally, and truncated at zero (to avoid random realisations with negative costs or negative amounts of generation). For each of the scenarios, three million random realisations of the model are computed, for which averages and standard deviations are reported below.

3.5.2 Data Used in the Analysis

Data Sources

Data on electricity sector costs and production in Fiji are taken from various sources. The capital cost of projects is taken from a report on energy security drafted for the Government of Fiji by Snowy Mountains Engineering Corporation (2009), which includes data supplied by the FEA (some of it from 2008). The accuracy of this data is verified using publicly available sources such as FEA annual reports and press releases, Commerce Commission tariff determinations, interviews and presentations by IPPs, and news clippings. No accurate figures could be obtained for O&M costs in Fiji, although some information was available from news reports and statements by FEA or Commerce Commission officials. As a result, the data for operation and maintenance costs is taken from a World Bank report published in 2006, *Technical and Economic Assessment of Grid, Mini-Grid and Off-Grid Electrification.* Again, the reliability of those figures has been verified where possible against publicly available information in Fiji, including statements by the Commerce Commission and the FEA.

Generally speaking, data on the cost of electricity generation in Fiji is poor. The FEA was unwilling to provide any information beyond what was already publicly available. The FEA makes detailed submissions to the Commerce Commission when tariff levels are being reviewed, however the Commerce Commission is unable under its legislation to share information from those submissions (Communication with Commerce Commission, July 2009).[52] Data on historical power generation from each technology are taken from FEA annual reports. Monthly data are used to measure variability of electricity generation cost and output from hydro and wind-power stations (both technologies experience considerable seasonal variation in output). Monthly data for hydro-based generation are only available from 2004 to 2010, excluding 2009.

[52] The Commerce Commission does make some data public in its tariff determinations, listing the per unit cost of electricity generation for oil and hydro-power technologies. Where appropriate, those figures have been used to verify the accuracy of other data. However that Commerce Commission data alone is not sufficient for this analysis, as it does not: a) distinguish between capital cost and O&M costs, b) specify the discount rate that is used to determine levelised per unit costs, c) state whether transmission and distribution costs are included in the analysis, or d) state the periods for which those costs are relevant.

Data on energy efficiency measures are taken from a 2011 report by George Wilkenfeld and Associates Pty Ltd (GWA 2011). The findings of this report were verified wherever possible with other relevant data and the author's own calculations, although it should be noted that data on energy efficiency in the Pacific islands are scarce. The costs provided by George Wilkenfeld and Associates Pty Ltd (2011) are calculated using a discount rate of 7 per cent.[53]

Electricity Supply and Demand Reduction Costs

Present and future electricity generation costs in Fiji are calculated using a 5 and 10 per cent discount rate, and are shown in table 3.5.2a.[54] The cost of power production from generation capacity that the FEA could install by 2025 is calculated using data on new investments being undertaken by the FEA, and cost reduction forecasts in the *World Energy Outlook, 2008* (IEA 2008).

[53] Cost data for a 5 or 10 per cent discount rate were not provided in the report, and a lack of detail on how these figures were arrived at made it impossible to make such calculations. The use of this data in the model is therefore less than ideal, although it should be noted that the costs of avoided electricity demand achieved through all energy efficiency measures is far lower than the cheapest form of electricity generation in Fiji, irrespective of whether these are calculated using a 5 or 10 per cent discount rate. In addition, undiscounted costs calculated in George Wilkenfeld and Associates Pty Ltd (2011) are not dramatically different to those calculated with a 7 per cent discount rate, with energy efficiency measures significantly cheaper than generation of electricity from renewable technologies.

[54] The capital cost of existing capacity is included in the analysis, given that the modelling explores a range of defined scenarios rather than attempting to identify a theoretical optimum.

Table 3.5.2a. Present and Expected Future Costs of Electricity Generation in Fiji for Different Technologies (FJc/kWh)

	5 per cent Discount Rate		10 per cent Discount Rate	
	Existing Costs	Future Costs	Existing Costs	Future Costs
Existing Hydro-power	11.76		19.51	
New Hydro-power		20.62		35.13
Oil-power	36.11	44.39	37.81	45.81
Bagasse – FSC	22.08	13.90	28.00	16.47
Biomass – Tropik Wood	18.66	16.80	23	20.70
Biomass – IPPs		21.08		23
Wind-power	66.07	39.35	91.62	54.46
Solar-power		32.87		47.55
Geothermal		14.20		20.79

*Existing and new hydro-power are treated separately owing the different type of hydro-power plants likely to be constructed (existing hydro-power is large-scale, whereas new hydro-power is relatively small-scale run-of-the-river).

In some cases, future costs differ significantly from present day costs. This is for various reasons, including:

Hydro-power – The cost of electricity from the Nadarivatu and other run-of-the-river schemes (new hydro-power) is higher than for the existing Monasavu hydro-power scheme (which involves water storage). This is because less electricity per unit of capacity is generated from run-of-the-river schemes than hydro-power schemes with water storage.[55] Future hydro-power projects in Fiji are likely to be similar to the Nadarivatu hydro-power plant. At a system-wide level, run-of-the-river schemes are also more costly, as more back-up oil-power capacity is required due to their highly variable output (FEA 2007b). This means that in the model, technology portfolios with significant new hydro-power capacity require more back-up oil-based generation capacity.

[55] For example, the Monasavu scheme has a capacity of 72 MW and generates approximately 400 GWh of electricity each year. The 41 MW Nadarivatu project will have more than half the capacity of the Monasavu scheme, but is expected to generate only 101 GWh annually (or one quarter of the output of the Monasavu scheme).

Oil-based generation – Future generation costs are based on oil price forecasts from the IEA, which predicts higher prices in 2025 as a result of growing demand for oil and the possible "peaking" of oil production (as outlined in chapter one) (IEA 2010).

Bagasse – Current co-generation capacity used by the FSC is dated. The electricity generation costs of bagasse-fired power generators that are now available for installation (new bagasse) are significantly lower (Interviews with FSC, August 2009).

Wind-power and solar-power – These are high-cost renewable technologies, although the IEA forecasts significant cost reductions by 2025. Wind-power costs will remain expensive by international standards in Fiji as a result of low wind speeds.

The costs of reducing demand for electricity through energy efficiency measures using appliance labelling and MEPS are shown in table 3.5.2b. Data in the table are given for each source of electricity consumption described in section 3.3.

Table 3.5.2b. Energy Efficiency Measures: The Cost of Avoided Electricity Demand

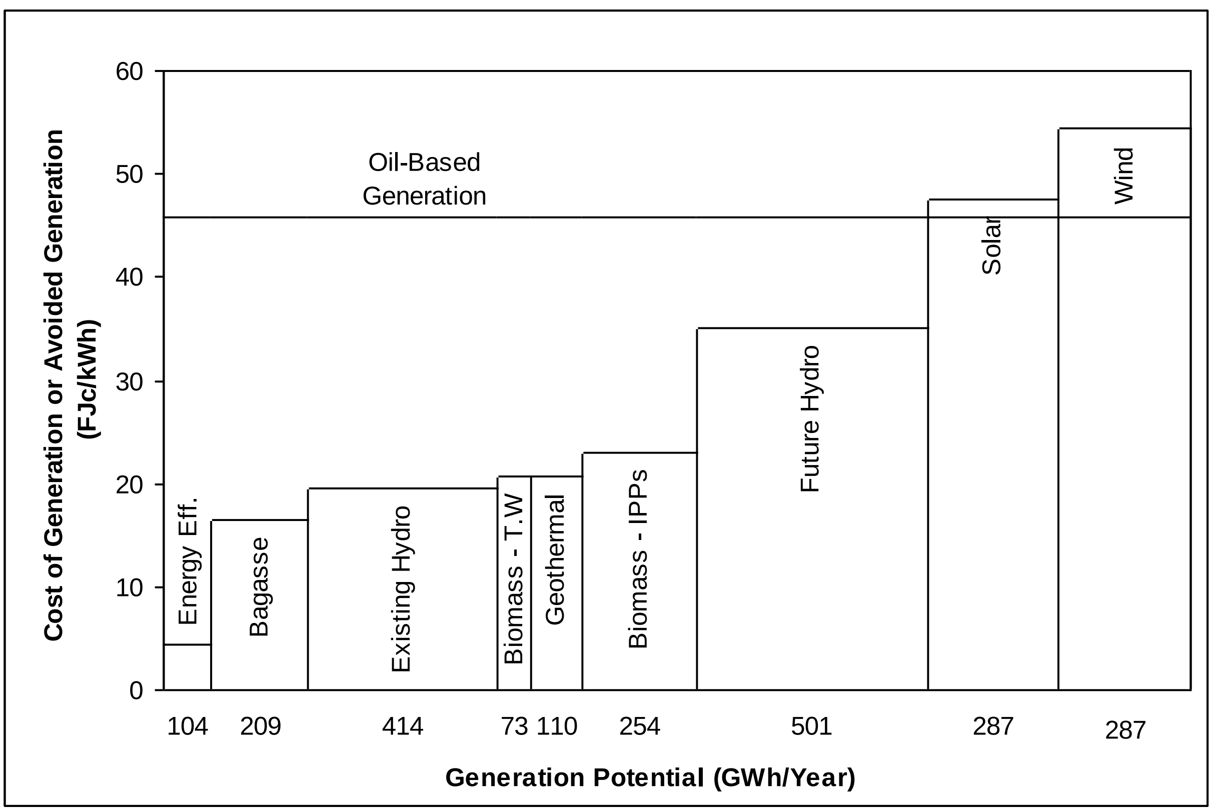
Energy Efficiency Measure	Cost of Avoided Electricity Demand in 2025 (FJc/kWh)
Residential refrigeration	6.77
Residential freezers	3.92
Residential air conditioning	2.14
Residential lighting	1.60
Comm/Govt Refrigeration	5.70
Comm/Govt Air Con	7.66
Comm/Govt Lighting	3.92
Weighted Average	4.45

Source: George Wilkenfeld and Associates Pty Ltd (2011)

The cost effectiveness of reducing electricity demand through implementation of labelling and MEPS frameworks differs for each energy efficiency measure. Nonetheless, the costs of energy efficiency measures are all significantly lower on a FJc/kWh basis than the costs of generation from any technology. The model incorporates an aggregate energy efficiency measure for the sake of simplicity, given that the scope for each individual energy efficiency measure is relatively small in terms of gigawatt hours saved per year (as discussed in section 3.3.2). The uniform cost of energy efficiency measures is calculated as the weighted average cost of avoided electricity demand (in FJc/kWh), with the relative weight of individual energy efficiency measures based on the scope they provide for energy savings.

A cost curve of generation options is shown in figure 3.5.2a. The vertical axis displays the costs of generation or avoided demand (in FJc/kWh), while the horizontal axis displays potential annual electricity generation/savings (in GWh per year) discussed in sections 3.2 and 3.3. Future generation costs looking forward to 2025 are used for all technologies and energy efficiency measures, with the exception of "existing hydro", which will remain in place in 2025. The cost of oil-based generation is shown as a line, as there is no limit placed on oil-based generation in the analysis. All generation costs are calculated using a 10 per cent discount rate (with the exception of energy efficiency measures, which are calculated using a 7 per cent discount rate).

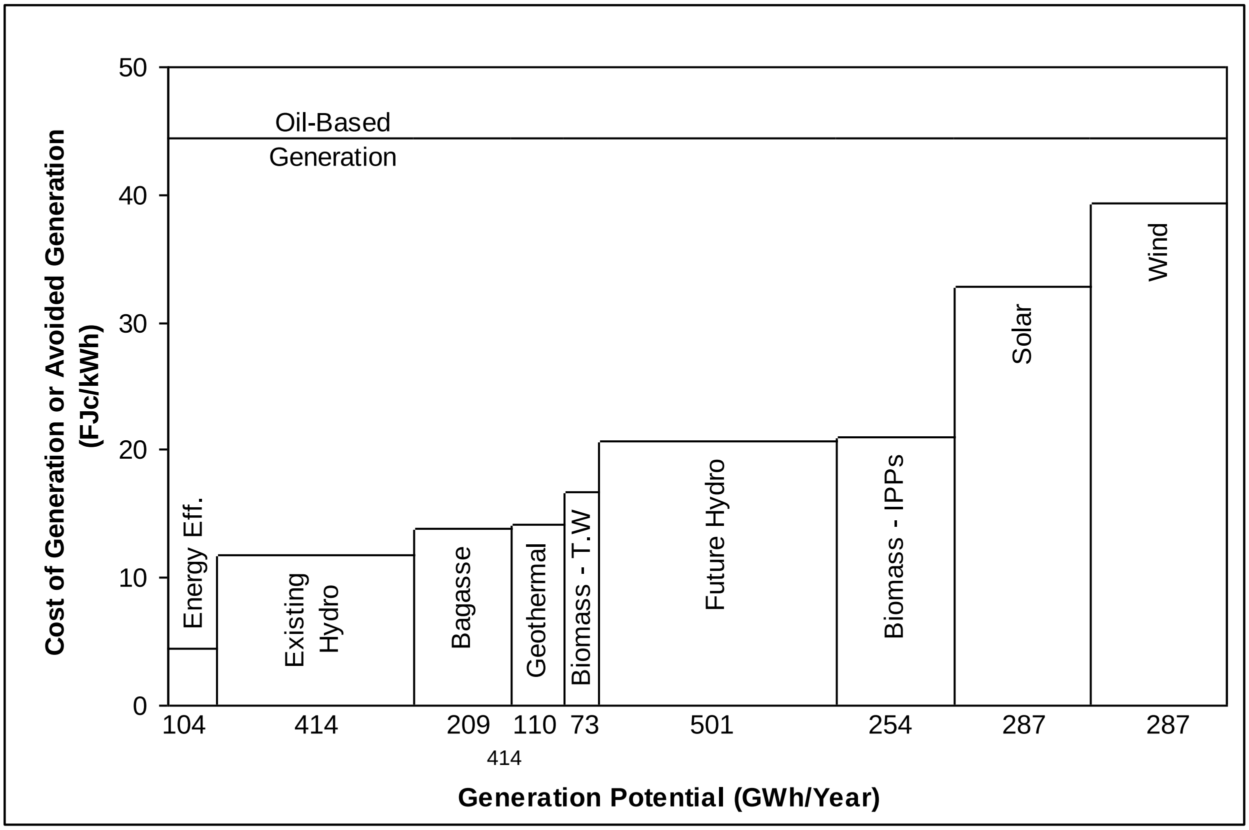
Figure 3.5.2a. Cost Curve of Technologies for Electricity Supply in Fiji, 2025 (using a 10 per cent discount rate)



Energy efficiency measures are the cheapest option in Fiji for meeting/avoiding electricity demand in 2025, although the scope for such measures is modest. Most renewable technologies provide electricity at a lower cost than oil-based generation, especially bagasse, biomass, geothermal and existing hydro-power (or large-scale hydro-power with storage capacity). Future hydro-power schemes such as the Nadarivatu scheme have a higher generation cost than these renewable technologies, although generation costs for future hydro-power schemes are nonetheless lower than for oil-based generation. Electricity generation from solar and wind-power remains more expensive than oil-based generation looking forward to 2025, when costs are calculated using a 10 per cent discount rate.

Renewable-based electricity generation costs decline relative to oil-based generation if a 5 per cent discount rate is used, as illustrated in figure 3.5.2b. Most significant are the changes in generation costs associated with capital-intensive renewable technologies. Existing hydro-power replaces bagasse as the cheapest generation technology in the new scenario. Generation costs from new hydro-power plants are also significantly lower in such a scenario, being less than those of power production from biomass. The cost of electricity generation from solar and wind-power also declines substantially, becoming cheaper than oil-based generation. Geothermal-based power generation becomes cheaper than generation from biomass.

Figure 3.5.2b. Cost Curve of Technologies for Electricity Supply in Fiji, 2025 (using a 5 per cent discount rate)



Financial Risk

Financial risk in the model is represented by the standard deviation of expected levelised average power generation costs. In other words, risk is the variability of cost outcomes for each technology, and is estimated based on past cost outcomes (as is always the case in analysis based on portfolio theory). For oil-based power generation, risk is largely determined by the variability of oil prices (oil is the most significant component of oil-based electricity generation costs). The model calculates oil price risk using monthly data for FEA oil-based generation costs between 2002 and 2010. Although this represents a period when oil prices were particularly volatile, the use of these numbers for future oil price volatility can be justified on the basis of analysis from the IEA and EIA, both of which forecast considerable oil price volatility (as outlined in chapter two) (EIA 2010; IEA 2008). Capital cost risk associated with oil-based production is taken from World Bank data used in various other portfolio analyses (Allana, et al. 2011; Awerbuch and Yang

2008; Bacon, et al. 1996). The same World Bank data are used to estimate variation in levelised power generation costs for renewable technologies (Allana, et al. 2011; Awerbuch and Yang 2008; Bacon, et al. 1996).[56]

The financial risk associated with each technology is shown in table 3.5.2c. Standard deviations for each technology are divided by the mean cost in order to calculate the proportional standard deviation.[57] Adoption of the financial risk data shown in table 3.5.2c involves a number of assumptions. First, it assumes that the past is a good guide to the future, or at the very least, a better guide than forecasts alone. This is an intuitive approach; if not always correct. Most financial analysis relies heavily on empirical observations of the past. Second, the way in which the data are used in the model assumes that there is no cost correlation between technologies, (or in other words, that the cost streams of technologies are independent from one another). This is a reasonable assumption given that biomass fuel from Fiji is not exported (in global markets, there is some correlation between biomass and fossil fuels). The impact of correlation in a portfolio analysis was discussed in chapter two. Third, a focus on financial risk alone means that non-financial risk is not considered. This is a serious shortfall of the model, and means that the results should be interpreted with care. However the focus on financial risk alone is also necessary for "operationalisation" of the data – there is no firm basis on which to consider both financial and non-financial risk in a financial model (nor is there adequate data for the electricity sector in Fiji).

[56] Construction risks for hydro-power differ on the basis of whether projects are "large-scale" or "small-scale". Large-scale hydro-power projects are said by the World Bank to have a construction risk of 0.38 standard deviations, whereas small-scale projects are said to have a construction risk of 0.10 standard deviations. The definitions of these "scales" are not made clear. Future hydro-power projects in Fiji, which should be similar or smaller in size than the Nadarivatu project, are assumed here to be closer in size to "small-scale" projects. Construction risk in the model is therefore assumed to be 0.17 standard deviations, or one-quarter of the way between "small-scale" and "large-scale" projects.

[57] This method is common practice and is similar to the use of a coefficient of variation to represent risk (Copeland, et al. 2005).

Table 3.5.2c. Financial Risk of Different Technologies (proportional standard deviation* of historical costs)

	Construction Risk (does not apply to existing generators)	Operation &Maintenance Risk	Fuel Price Risk	Weighted Average Risk**
Oil-power - New	0.23	0.24	0.28	0.27
Oil-power - Existing	n.a	0.24	0.28	0.23
Hydro-power - New	0.17	0.15	n.a	0.17
Hydro-power - Existing	n.a	0.15	n.a	0.01
Bagasse - New	0.20	0.11	n.a	0.16
Biomass - New	0.20	0.11	n.a	0.17
Biomass - Existing	n.a	0.11	n.a	0.04
Wind-power - New	0.05	0.08	n.a	0.05
Wind-power - Existing	n.a	0.08	n.a	0.01
Solar-power - New	0.05	0.03	n.a	0.05
Geothermal - New	0.15	0.15	n.a	0.15

* Standard deviation of expected levelised average cost / average cost
** When levelised costs are calculated using a 10 per cent discount rate

Financial risk associated with energy efficiency measures is assumed to be zero in the model. There are risks associated with establishing labelling and MEPS frameworks in order to promote energy efficiency products; however these risks are institutional in nature and cannot be quantified. Institutional risks are also present in the implementation of all the generation technologies discussed above, and are similarly not quantified or incorporated in the model. Such risks are instead discussed in chapter four where relevant.

3.6 Modelling Results and Analysis

This section presents results from the portfolio analysis. It begins by describing the reference scenarios used in the modelling, which are outlined in table 3.6a. It then looks at the cost and financial risk implications of different portfolios of generation technologies using a 10 per cent discount rate. The section conducts sensitivity analyses of these results using a 5 per cent discount rate and variations in future oil prices. It also examines the cost and financial risk implications of different aggregate levels of electricity generation in 2025. The discussion at the end highlights some policy implications arising from the analysis.

Table 3.6a Technology Portfolios used in the Modelling

Scenario Group	Technology Portfolio	Features
Reference Scenarios	Existing Renewable Capacity	No new investment in renewable technologies
	FEA 2008 Baseline Scenario	52.3 MW additional hydro capacity 25.8 MW bagasse capacity 20 MW additional biomass 1 capacity
	FEA 2015 Renewable Energy Target Scenario	76.57 MW additional hydro capacity 56 MW bagasse capacity 36.3 MW of (new) biomass 2 capacity. 4 MW of new geothermal capacity
FEA 2015 Scenarios with Additional Investment in Renewable Technologies	FEA 2015 scenario plus additional bagasse, biomass, geothermal and energy efficiency measures	Renewable technology capacity in the FEA 2015 scenario, plus an additional: • 34 MW bagasse capacity • 20 MW of biomass 1 capacity • 11 MW geothermal capacity • energy efficiency measures equivalent to 11.9 MW of "generation capacity"
	FEA 2015 scenario plus additional wind and solar	Renewable technology capacity in the FEA 2015 scenario, plus an additional: • 30 MW wind capacity • 10 MW solar capacity
	FEA 2015 scenario plus additional hydro	Renewable technology capacity in the FEA 2015 scenario, plus an additional: • 82 MW hydro capacity
	FEA 2015 scenario plus additional geothermal	Renewable technology capacity in the FEA 2015 scenario, plus an additional: • 11 MW geothermal capacity
	FEA 2015 scenario plus additional biomass and bagasse	Renewable technology capacity in the FEA 2015 scenario, plus an additional: • 20 MW biomass 1 capacity • 34 MW bagasse capacity
	FEA 2015 scenario plus energy efficiency measures	Renewable technology capacity in the FEA 2015 scenario, plus an additional: • energy efficiency measures equivalent to 11.9 MW of "generation capacity"
FEA 2015 Scenarios without Renewable Technology Investments	FEA 2015 scenario with no bagasse	Renewable technology capacity in the FEA 2015 scenario, less: • 56 MW bagasse capacity
	FEA 2015 scenario with no new biomass or geothermal	Renewable technology capacity in the FEA 2015 scenario, less: • 36.3 MW biomass 2 capacity • 4 MW geothermal capacity
	FEA 2015 scenario with no new hydro	Renewable technology capacity in the FEA 2015 scenario, less: • 26.6 MW new hydro

3.6.1 FEA Reference Scenarios

The reference scenarios used in the model include the existing renewable technology scenario, the FEA 2008 baseline scenario, and the FEA 2015 renewable energy target scenario.

The Existing Renewable Capacity Scenario

This scenario includes no new investment in renewable technologies, not even the Nadarivatu hydro-power scheme. Existing renewable technology capacity is assumed to remain in place, with additional demand in 2025 met by oil-based power generation.

The FEA 2008 Baseline Scenario

The FEA 2008 baseline scenario is based on power sector forecasts made by the FEA in 2008 for planning purposes (SMEC 2009). These forecasts predict that total electricity generation will have reached 1435 GWh by 2025. In addition to generation technologies that are already installed, the FEA reference scenario forecasts:

- 52.3 MW additional hydro-based generation capacity. Most of this (41 MW) will come in the form of the Nadarivatu scheme that should be completed by 2012;
- 25.8 MW bagasse capacity. All of this capacity will be new, given that existing bagasse-fired generators are already nearing the end of their economic lives; and
- 20 MW additional biomass 1 capacity. This additional capacity at the Tropik Wood plant had been planned for 2008 but was cancelled as a result of the problems with its existing generator (FEA 2008a; FEA 2009a; FEA 2010; SMEC 2009).

No new wind-power capacity is included in the FEA 2008 baseline scenario. In addition, the scenario does not forecast any geothermal or solar-based power production in 2025.

The FEA 2015 renewable energy target scenario (referred to below as the FEA 2015 scenario) builds on the FEA 2008 baseline scenario, but includes additional investments announced by the FEA since 2008, which enable the FEA to meet its target of generating 90 per cent of electricity from renewable technologies by 2015. The FEA 2015 scenario forecasts:

- 76.57 MW additional hydro-based generation capacity (24 MW more than that forecast in the 2008 FEA baseline scenario). This includes the Nadarivatu (41 MW) and Qaliwana schemes (19.7 MW), Wailoa downstream project (14.1 MW), and the raising of the Wainisavulevu weir;[58]
- 56 MW bagasse capacity. This includes 31 MW of capacity at Lautoka and Labasa, and 24 MW of capacity at the Rarawai mill in Ba. It is assumed that looking forward to 2025, existing capacity will be replaced;
- 36.3 MW of new biomass 2 capacity. This includes the proposed Vuda (17.8MW) and Labasa (8.5MW) biomass plants, and an additional 10 MW plant to be constructed by 2018. Production costs at these facilities will vary to those at the existing Tropik Wood plant, as described in section 3.2.2; and
- 4 MW of new geothermal capacity at Savusavu.

The new investments described in the FEA 2015 scenario are ambitious. The assumed investment by the FSC in particular seems unlikely, given the current state of the sugar industry. Some of the FEA’s output forecasts are also optimistic. For example, the potential for a geothermal-power plant at Savusavu assumes that the linking of the Savusavu and Labasa power grids will occur by 2015, and upfront costs associated with exploration will be met by IPPs. This is an optimistic assumption for the year 2015. Similarly, the capacity factors that are assumed are in some cases too high (as outlined in the discussion regarding

[58] The Wainisavulevu weir raising project will not involve any new generation capacity, but will allow for additional generation of approximately 7 GWh at the Monasavu scheme. This is equivalent to 2.77 MW capacity for the purposes of the model.

biomass in section 3.2.2). This means that generation from renewable technologies is unlikely to amount to 90 per cent of total generation in 2015.

3.6.2 Cost and Risk Implications of Different Technology Portfolios

The cost and risk implications of different technology portfolios are discussed below. The modelling results that are discussed are calculated using a 10 per cent discount rate. An overview of the portfolios, including the installed capacity of each technology and the renewable technology share of output, is included in table 3.6.2a. The cost and risk features of different technology portfolios are illustrated in figures 3.6.2a, 3.6.2b, and 3.6.2d (figure 2.4.2a in chapter two provided an introduction to figures used in portfolio analysis).

Table 3.6.2a. Cost and Risk Implications of Different Generation Technologies and Scenarios (calculated using a 10 per cent discount rate)

	Existing renewable capacity	FEA 2008 baseline scenario	FEA 2015 renewable energy target	FEA 2015 plus bagasse, biomass geothermal and en. eff.	FEA 2015 plus wind and solar	FEA 2015 plus hydro	FEA 2015 plus geo	FEA 2015 plus bio & bagasse	FEA 2015 plus en. eff.	FEA 2015 with no bagasse	FEA 2015 no new biomass or geo	FEA 2015 with no new hydro	FEA with lower demand	FEA with higher demand
Expected levelised average cost (FJD/kWh)	0.356	0.336	0.295	0.244	0.299	0.309	0.286	0.284	0.272	0.314	0.330	0.295	0.284	0.313
Standard deviation of exp levelised avg cost	0.067	0.052	0.029	0.021	0.027	0.026	0.025	0.023	0.024	0.037	0.046	0.032	0.020	0.039
Capacity (MW)														
Model Input														
Existing hydro	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7	88.7
New hydro	0.0	51.0	77.6	0.0	77.6	160.0	77.6	77.6	77.6	77.6	77.6	51.0	77.6	77.6
Bagasse	0.0	25.8	56.0	90.0	56.0	56.0	56.0	90.0	56.0	0.0	56.0	56.0	56.0	56.0
Biomass 1	9.3	29.3	9.3	29.3	9.3	9.3	9.3	29.3	9.3	9.3	9.3	9.3	9.3	9.3
Biomass 2	0.0	0.0	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3	0.0	36.3	36.3	36.3
Wind	10.0	10.0	10.0	10.0	40.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Solar	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	4.0	15.0	4.0	4.0	15.0	4.0	4.0	4.0	0.0	4.0	4.0	4.0
Energy eff.	0.0	0.0	0.0	11.9	0.0	0.0	0.0	0.0	11.9	0.0	0.0	0.0	0.0	0.0
Model Output														
Oil	148.4	143.1	112.1	88.9	107.2	112.1	102.7	110.2	100.1	116.0	144.4	112.0	78.8	145.2
Total capacity	256.4	347.9	393.9	370.1	429.1	476.4	395.6	446.0	393.9	341.9	386.0	367.3	360.7	427.0
Capacity shares														
Renewables	42%	59%	72%	76%	75%	76%	74%	75%	75%	66%	63%	70%	78%	66%
Oil	58%	41%	28%	24%	25%	24%	26%	25%	25%	34%	37%	30%	22%	34%

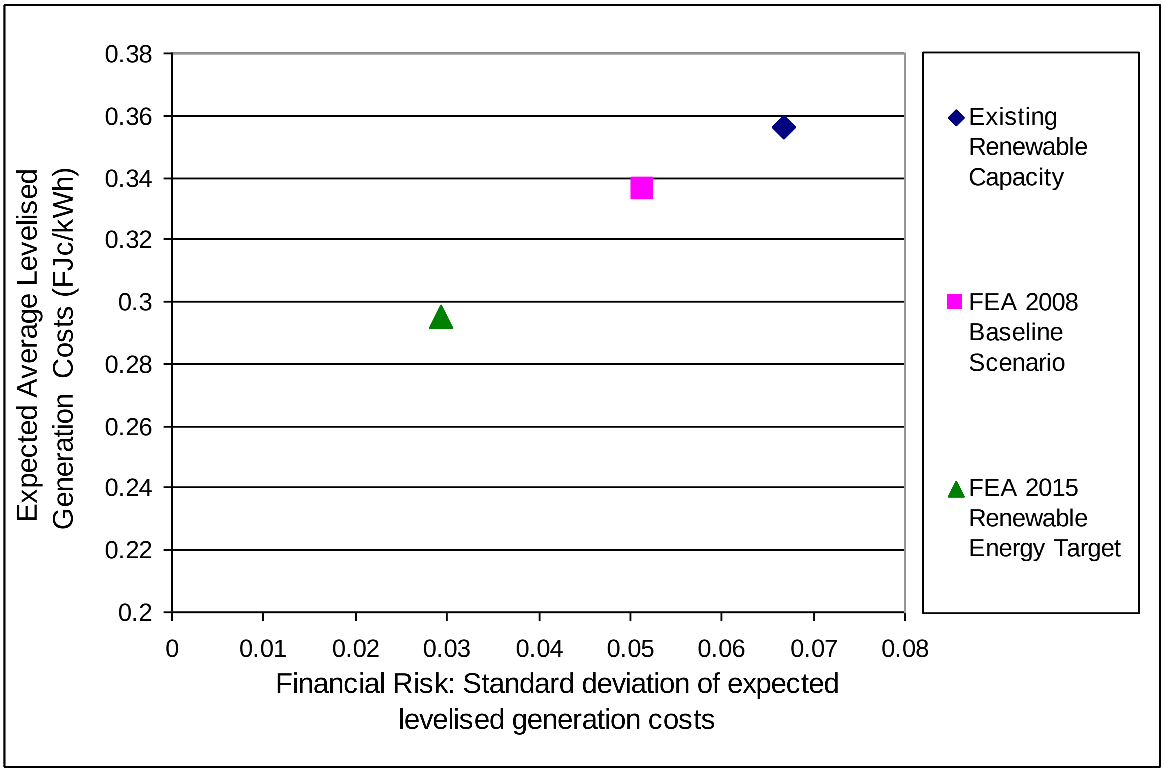
	Existing renewable capacity	FEA 2008 baseline scenario	FEA 2015 renewable energy target	FEA 2015 plus bagasse, biomass geothermal and en. eff.	FEA 2015 plus wind and solar	FEA 2015 plus hydro	FEA 2015 plus geo	FEA 2015 plus bio & bagasse	FEA 2015 plus en. eff.	FEA 2015 with no bagasse	FEA 2015 no new biomass or geo	FEA 2015 with no new hydro	FEA with lower demand	FEA with higher demand
Expected levelised average cost (FJD/kWh)	0.356	0.336	0.295	0.244	0.299	0.309	0.286	0.284	0.272	0.314	0.330	0.295	0.284	0.313
Standard deviation of exp levelised avg cost	0.067	0.052	0.029	0.021	0.027	0.026	0.025	0.023	0.024	0.037	0.046	0.032	0.020	0.039
Annual Output (GWh)														
Existing hydro	413.8	413.8	413.8	413.7	413.8	413.8	413.6	413.8	413.8	413.9	413.7	413.9	413.8	413.8
New hydro	0.0	121.9	185.5	0.0	185.5	382.4	185.4	185.5	185.5	185.6	185.4	122.0	185.5	185.5
Bagasse	0.0	60.2	130.6	209.8	130.6	130.6	130.7	209.8	130.7	0.0	130.6	130.8	130.7	130.8
Biomass 1	23.3	73.4	23.3	73.4	23.3	23.3	23.3	73.4	23.3	23.3	23.3	23.3	23.3	23.3
Biomass 2	0.0	0.0	250.9	250.9	250.9	250.9	250.9	250.9	250.9	250.9	0.0	250.9	250.9	250.9
Wind	6.1	6.1	6.1	6.1	24.4	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Solar	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	29.4	110.2	29.4	29.4	110.2	29.4	29.4	29.4	0.0	29.4	29.4	29.4
Energy eff.	0.0	0.0	0.0	102.8	0.0	0.0	0.0	0.0	102.8	0.0	0.0	0.0	0.0	0.0
Oil	991.8	759.6	405.3	284.5	366.4	277.8	333.0	306.1	313.8	527.3	676.4	461.2	174.0	682.7
Total output	1435.0	1435.0	1444.8	1451.5	1448.8	1514.3	1453.2	1474.8	1456.4	1436.5	1435.6	1437.4	1213.7	1722.6
Output shares														
Renewables	31%	47%	72%	80%	75%	82%	77%	79%	78%	63%	53%	68%	86%	60%
Oil	69%	53%	28%	20%	25%	18%	23%	21%	22%	37%	47%	32%	14%	40%

Existing renewable capacity scenario – This is a "worst case" scenario, being the technology portfolio with the highest expected average generation cost and financial risk, as shown by the point in the top right hand corner of figure 3.6.2a. It represents a technology portfolio in which the FEA has made no further investment in renewable technologies, and only existing renewable capacity provides electricity. Most electricity production (69 per cent) comes from oil-based generation capacity as a result. The share of oil-based generation capacity is not as high (at 58 per cent), due to the higher capacity factor of oil-based generation.

FEA 2008 baseline scenario – Adding renewable generation capacity forecast in the FEA 2008 baseline scenario reduces both expected average portfolio generation cost and financial risk. The reason for this is that investment in renewable technology capacity decreases oil-based generation, which has high generation costs and involves significant financial risk. Expected portfolio generation costs fall by 2 FJc/kWh. The proportional decline in financial risk is bigger, with a decline from 0.067 to 0.052 standard deviations. Oil-based electricity production falls from 69 per cent of total generation in the "existing renewable capacity scenario" to 53 per cent in the FEA 2008 baseline scenario. Although this is significant, the reduction is rather modest when compared to that in other technology portfolios where there are substantial investments in low-cost, low-risk renewable technologies.

FEA 2015 renewable energy target scenario – This technology portfolio includes substantial investment in renewable technologies forecast by the FEA for 2015 (as outlined above). Electricity generation from renewable technologies accounts for 72 per cent of total generation as a result. This is lower than the 90 per cent target established for 2015, owing to the expansion of demand for electricity by 2025. The renewable technology share of total generation capacity is also 72 per cent. The expected average generation cost of 29.5 FJc/kWh is lower than in both the existing renewable technology portfolio (35.6 FJc/kWh) and the 2008 FEA baseline scenario (33.6 FJc/kWh). Financial risk is significantly lower at 0.029 standard deviations.

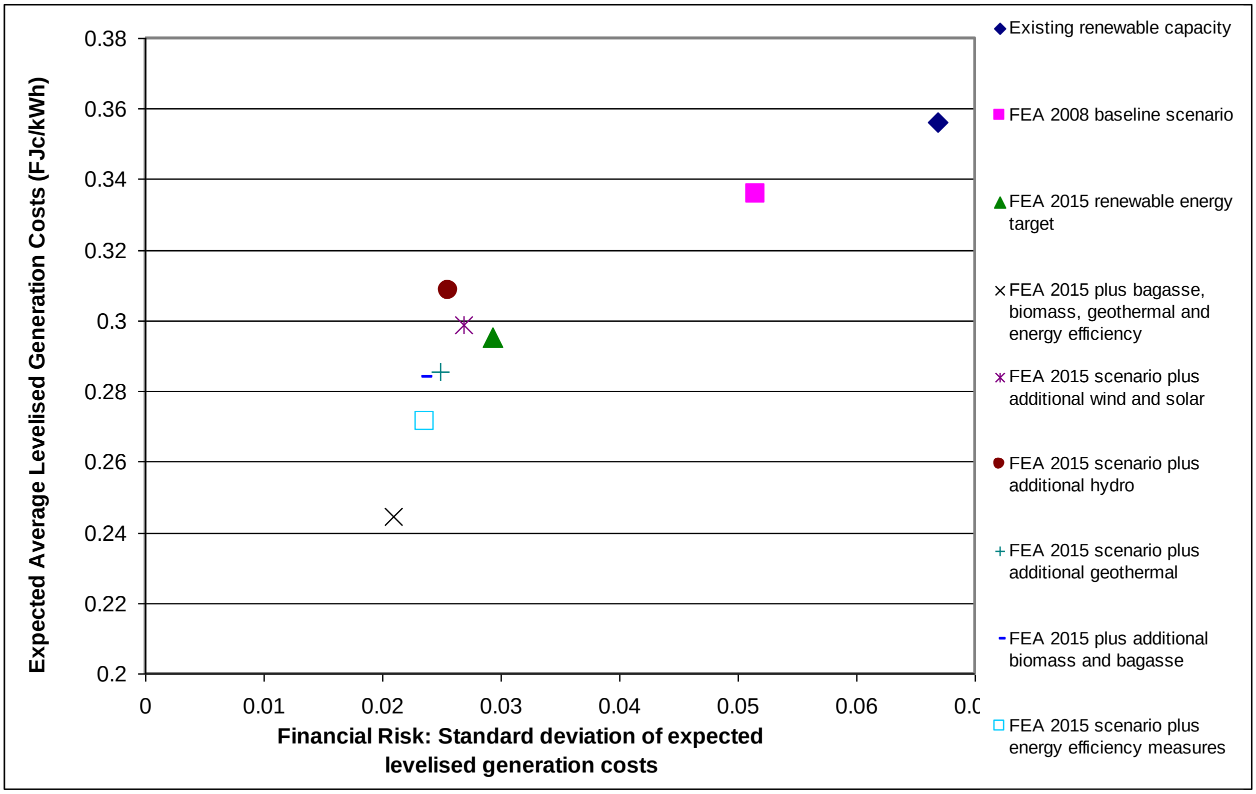
Figure 3.6.2a. Cost and Risk Implications of Baseline Portfolios of Electricity Generation Technologies in 2025



Modelling Results: FEA 2015 Scenario with Additional Investment in Renewable Technologies

Cost and risk implications of investments in renewable technologies that are additional to the FEA 2015 scenario are shown in figure 3.6.2b. The three reference scenarios are also included in the figure for purposes of comparison.

Figure 3.6.2b. Cost and Risk Implications of the FEA 2015 Portfolio with Additional Investment in Renewable Technologies



FEA 2015 scenario plus additional bagasse, biomass, geothermal and energy efficiency measures – This "best case" scenario has the lowest expected average generation cost and financial risk of all the technology portfolios examined. Generation costs are 24.4 FJc/kWh, or 5 FJc/kWh less than in the FEA 2015 scenario, and are 11 FJc/kWh less than in the existing renewable capacity scenario. Financial risk is 0.021 standard deviations, lower than the 0.029 standard deviations in the FEA 2015 scenario, and significantly lower than in the other two reference scenarios.

This "best case" result is unusual in portfolio analysis. Other applications of portfolio analysis to the electricity sector typically involve a trade off between high-risk, low-cost and low-risk, high-cost technology portfolios, as was discussed in chapter two. The difference in the Fiji grid is that certain renewable technologies are both low-cost and low-risk relative to the oil-based generation that they replace.

The “best case” scenario involves significant investment in renewable technologies additional to that in the FEA 2015 scenario. The renewable technology share of total generation capacity is 76 per cent, moderately higher than in the FEA 2015 scenario. Output from renewable technologies is significantly higher at 80 per cent of total power production, due to investment in renewable technologies with high capacity factors (see table 3.6.2a).

FEA 2015 scenario plus additional wind and solar – Investment in 30 MW of additional wind-power capacity (in addition to the existing 10 MW of installed capacity) and 10 MW of solar-power capacity reduces portfolio risk but marginally increases generation costs compared to the FEA 2015 scenario. This is the result of displacement of oil-based generation by wind and solar-based generation, which is low-risk but has higher levelised generation costs when calculated using a 10 per cent discount rate. Renewable-based power generation accounts for 75 per cent of total generation in this scenario; which is only a small reduction on that in the FEA 2015 scenario, due to the low capacity factor of wind and solar-power technologies.

FEA 2015 scenario plus additional hydro – This technology portfolio includes 160 MW of new hydro-power capacity, 82 MW more than in FEA 2015 scenario. The renewable technology share of total generation capacity increases only modestly as a result of this investment, reaching 76 per cent. This small increase is due to the requirement for back-up capacity (oil-based generation capacity does not decline in absolute terms as a result of the additional investment in hydro-power). The renewable technology share of total output increases to 82 per cent from 72 per cent in the FEA 2015 scenario (see table 3.6.2a).

The additional investment in hydro-power reduces financial risk compared to all three reference scenarios; with risk declining to 0.026 standard deviations from the 0.029 standard deviations in the FEA 2015 scenario. Generation costs increase modestly when compared to the FEA 2015 scenario: rising from 29.5 FJc/kWh to 30.9 FJc/kWh. This is unexpected, given the lower generation costs of hydro-power compared to oil-based generation.[59] The result arises because of excess capacity in the portfolio: in certain

[59] Although generation costs in this scenario are still lower than in the FEA 2008 baseline scenario and the existing renewable capacity scenario (where there is no new investment in renewable technologies).

months, there is excessive electricity generation from renewable technologies. This means that output of the portfolio is 1514 GWh, higher than assumed demand for electricity of 1435 GWh. This finding is discussed in the next sub-section.

FEA 2015 scenario plus additional geothermal – This technology portfolio includes 15 MW of geothermal capacity (the upper limit that is assumed to be available to the grid in Fiji in this model), which is 9 MW more than forecast in the FEA 2015 scenario. The renewable technology share of total generation capacity increases as a result to 74 per cent, and its share of output increases to 77 per cent (see table 3.6.2a). Expected average generation costs and financial risk for the portfolio are lower as a result of the additional investment. Costs decline to 28.6 FJc/kWh, which is 1 FJc/kWh less than in the FEA 2015 scenario. Financial risk also declines as a result of the additional investment, from 0.029 to 0.025 standard deviations.

FEA 2015 scenario plus additional biomass and bagasse – This technology portfolio includes 29.3 MW of capacity at the Tropik Wood biomass plant (biomass 1) (20 MW more than in the FEA 2015 scenario), and 90 MW of bagasse capacity (34 MW more than in the FEA 2015 scenario). The renewable technology share of total generation capacity increases to 75 per cent, and its share of total output rises to 79 per cent (see table 3.6.2a). The additional investment modestly reduces generation cost to 28.4 FJc/kWh from 29.5 FJc/kWh in the FEA 2015 scenario. Financial risk declines to 0.023 from 0.029 standard deviations.

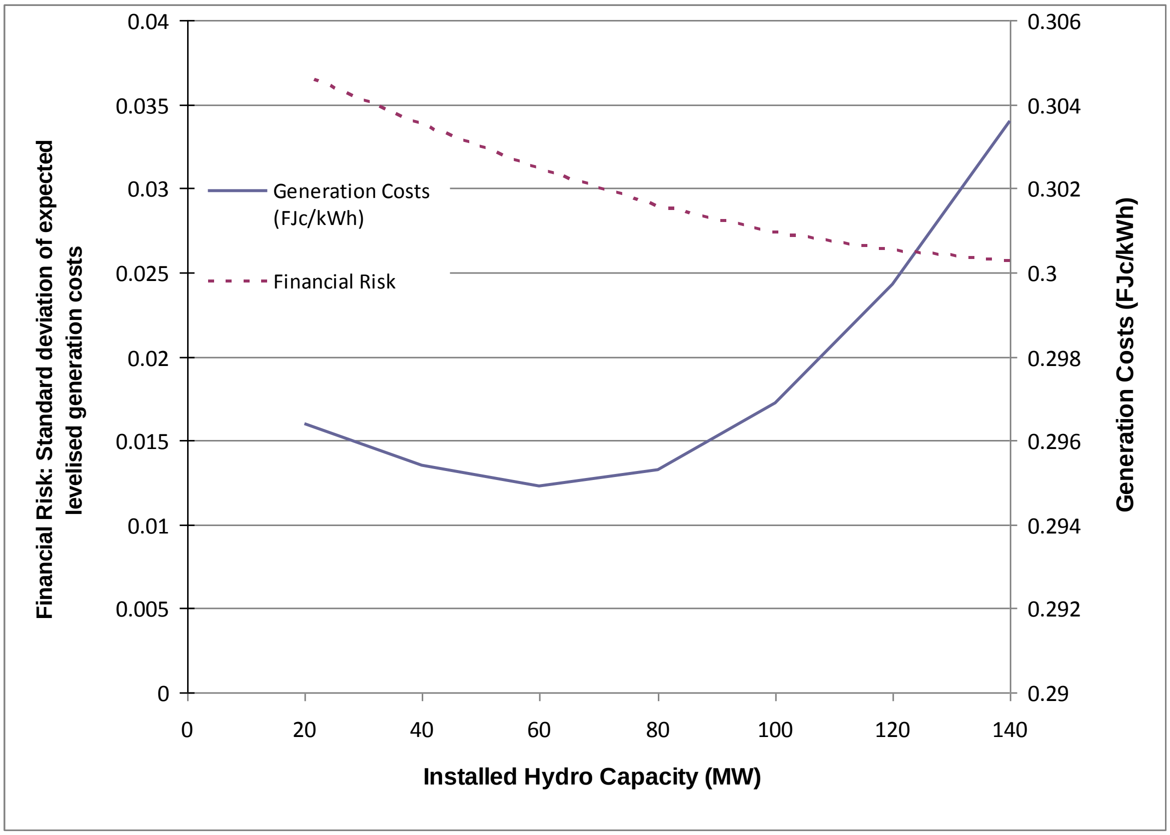
FEA 2015 scenario plus energy efficiency measures – The addition of energy efficiency measures to the FEA 2015 scenario, equivalent to 11.9 MW of capacity (consistent with the analysis in GWA (2011)), reduces expected average generation cost to 27 FJc/kWh, and lowers financial risk to 0.024 standard deviations. This is a significant decline given the limited scope given by the model to power savings from energy efficiency measures. The share of output from renewable technologies in the new portfolio is 78 per cent of total generation, and their share of total generation capacity is 75 per cent (treating “negawatts” produced through energy efficiency measures as kilowatts produced by renewable technologies). The extent of the cost and risk reductions in this technology portfolio are the result of the extremely low cost and risk of energy efficiency measures, relative to displaced generation (outlined in section 3.5.2). The gains from energy efficiency would be larger if other policy measures aimed at increasing energy efficiency were considered in the model.

Modelling Results: How Much Investment in Hydro-Power is Warranted?

Modelling results indicate that the technology portfolio with additional investment in hydro-power capacity has higher generation costs than the FEA 2015 scenario (as illustrated in figure 3.6.2b). This surprising result occurs because there is excess capacity in renewable technologies, which creates excess output in the portfolio in some months. Costs also increase due to the requirement for back-up oil-based generation capacity.

How much investment in hydro-power is warranted? The answer depends on the scenario being considered, and whether generation costs or financial risk take priority. Figure 3.6.2c illustrates the impact of additional hydro-power investment on the FEA 2015 scenario, as calculated using a 10 per cent discount rate. It shows that financial risk continues to decline with additional investment in hydro-based generation, although that decline slows with each additional megawatt of installed capacity. The impact of hydro-power investment on portfolio generation costs is different. Average generation costs decline modestly with additional investment in hydro-power until 60 MW of new hydro-power is installed. After this, generation costs rise at an increasing rate. It should be noted that the impact on costs of additional investment in hydro-power is minimal: at 140 MW of new hydro-power capacity, portfolio generation costs are less than 1 FJc/kWh higher than when hydro-power capacity is at its optimum in terms of generation costs.

Figure 3.6.2c The Impact of Hydro-power Investment on the FEA 2015 Scenario

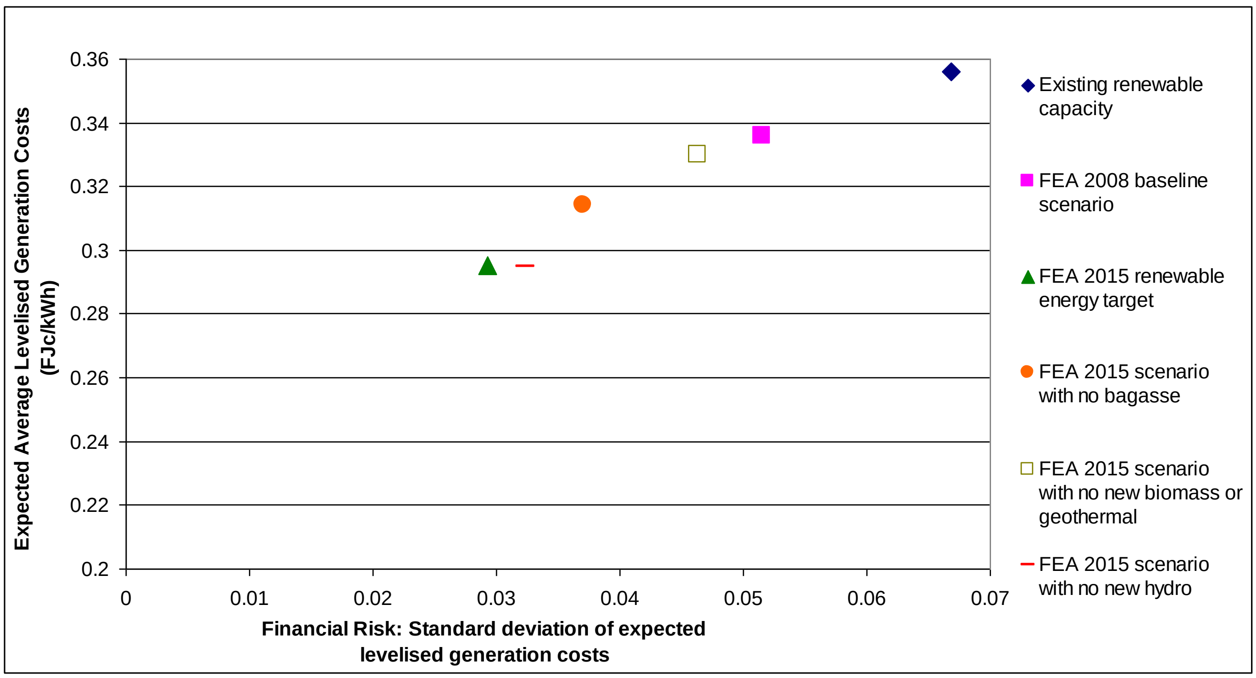


This cost-optimum level of hydro-power capacity is of course dependent on other investment forecast by the FEA. The discussion has already highlighted that such investment is not certain. If some of that investment in other technologies were to not occur, levels of hydro-power capacity higher than 60 MW could have lower portfolio generation costs than the 60 MW optimum. The conclusion to draw from the model is not therefore that the FEA's forecast 77.6 MW of new hydro-power capacity has higher generation costs than the cost-optimum capacity of 60 MW.[60] Rather, what can be argued on the basis of these results is that it may be better to prioritise investment in other renewable technologies over investment in new hydro-power capacity. Investment in hydro-power generation is not as attractive from a portfolio perspective, given its higher cost and the requirement for back-up capacity.

[60] Given the minimal impact on portfolio generation costs, investment additional to the 60 MW cost-optimum could be advocated as a risk mitigation measure against other forecast renewable technology investment not occurring. Similarly, the decline in financial risk could justify the very modest increase in generation costs, although this depends on the aversion to risk of the FEA.

The purpose of this section is to show what would happen if investment forecast in the FEA 2015 renewable energy target scenario were not to occur by 2025. This is very likely in the case of bagasse, and is possible for other technologies that require significant upfront investment, such as geothermal. Figure 3.6.2d illustrates the impact of renewable technology investment not occurring in the FEA 2015 scenario, with failed investment in renewable technologies replaced by increased oil-based generation capacity and output.

Figure 3.6.2d Cost and Risk Implications on the FEA 2015 Scenario of no Investment in Certain Renewable Technologies



FEA 2015 scenario with no bagasse – Expected average generation cost and financial risk both increase without electricity production from the sugar industry. Generation costs increase to 31.4 FJc/kWh from 29 FJc/kWh in the FEA 2015 scenario. Financial risk increases to 0.037 from 0.029 standard deviations. The renewable technology share of electricity production in this portfolio is lower than in the FEA 2015 scenario, declining from 72 to 63 per cent of total power generation. The capacity share of renewable technologies also declines, although not to the same extent, from 72 to 66 per cent of total generation capacity (see table 3.6.2a).

FEA 2015 scenario with no new biomass or geothermal – This technology portfolio excludes geothermal and new biomass capacity (the existing Tropik Wood biomass plant is included). It represents a scenario where there is no investment by new IPPs; something that could occur if the regulatory regime were not favourable to IPP investment. The renewable technology share of both total generation capacity and output is significantly lower in this portfolio than in the FEA 2015 scenario. The renewable technology share of total output declines from 72 to 53 per cent, while the capacity share declines from 72 to 65 per cent (see table 3.6.2a). This is mainly due to the lack of investment in biomass, which was forecast in the FEA 2015 scenario to generate 251 GWh of power. As a result, expected average generation cost increases to 32.9 FJc/kWh from 29.5 FJc/kWh in the FEA 2015 scenario. This is almost equal to expected average generation cost in the FEA 2008 baseline scenario. Financial risk also increases significantly, to 0.046 standard deviations from 0.029 standard deviations in the FEA 2015 scenario.

FEA 2015 scenario with no new hydro – The exclusion of all new investment in hydro-power capacity (although not the Nadarivatu scheme) has minimal impact on generation costs and financial risk in this technology portfolio. Generation costs in the portfolio remain at 29.5 FJc/kWh (they decline by 0.01 FJc/kWh), while financial risk increases modestly from 0.029 to 0.032 standard deviations. The impact of not investing in additional hydro-power is limited, despite a decrease in the renewable technology share of total output from 72 to 68 per cent (see table 3.6.2a). This raises questions about FEA prioritisation of investment in hydro-power over other renewable technologies.

Modelling Renewable Technology Investments: A Summary of Results

Investment in renewable technologies can generally be said to lower expected generation cost and financial risk (or risk that actual costs in the future will be significantly different to expected costs for the portfolio). It is difficult to directly compare declines in generation costs, measured in terms of FJc/kWh, and financial risk, which is measured by the standard deviation of historical movement in these costs. A comparison of percentage declines nevertheless provides some insights. The “best case” portfolio has generation costs of 24.4

FJc/kWh, a 31.5 per cent decrease on generation costs in the "worst case" existing renewable capacity portfolio. The proportional decline in financial risk associated with the same portfolios is bigger, at 68.2 per cent. This outcome is the result of the diversification effect of investment in renewables, which are assumed in the model to have no cost correlation with one another (as described in section 3.5.2) or with oil-based generation.[61]

Both FEA reference scenarios are an improvement on the existing renewable capacity scenario. The most significant improvement is in the FEA 2015 renewable energy target scenario, where substantial investments in low-cost, low-risk renewable technologies reduce portfolio generation costs and financial risk. The technology portfolio with the lowest expected generation cost and financial risk involves additional investment in energy efficiency, geothermal, biomass and bagasse technologies. Investment in wind and solar-power reduces financial risk but increases expected average power generation cost. The impact of investment in hydro-power is mixed. The worst case scenario for the FEA is one where there is no investment in renewable technology capacity. That would result in higher generation costs and significant financial risk for the electricity generation technology portfolio.

Certain renewable technologies have a more significant impact on portfolio generation costs and financial risk than others. Energy efficiency is particularly attractive, with no financial risk and very low generation costs, although the scope for power savings is assumed to be limited compared to demand in the modelling scenarios. Geothermal technology has low expected generation costs but limited resource availability. The most important low-cost, low-risk technology is new biomass, which like energy efficiency and geothermal, does not require back-up oil-based generation capacity (as outlined in section 3.5.1).[62] Bagasse and existing biomass capacity by comparison have low generation costs and minimal financial risk, but require back-up oil-based generation capacity.

New hydro-power capacity, which could be described as the FEA's flagship renewable technology investment, is not as beneficial in the model as the low-cost, low-risk

[61] The majority of expenses incurred for most renewable technologies are foreign. Potential correlation resulting from similar wages across industries in Fiji is therefore unlikely to be significant.
[62] This assumption is based on statements by the FEA and IPPs planning investment in Fiji. It is of course dependent on the adequacy of supplies of biomass for power generation.

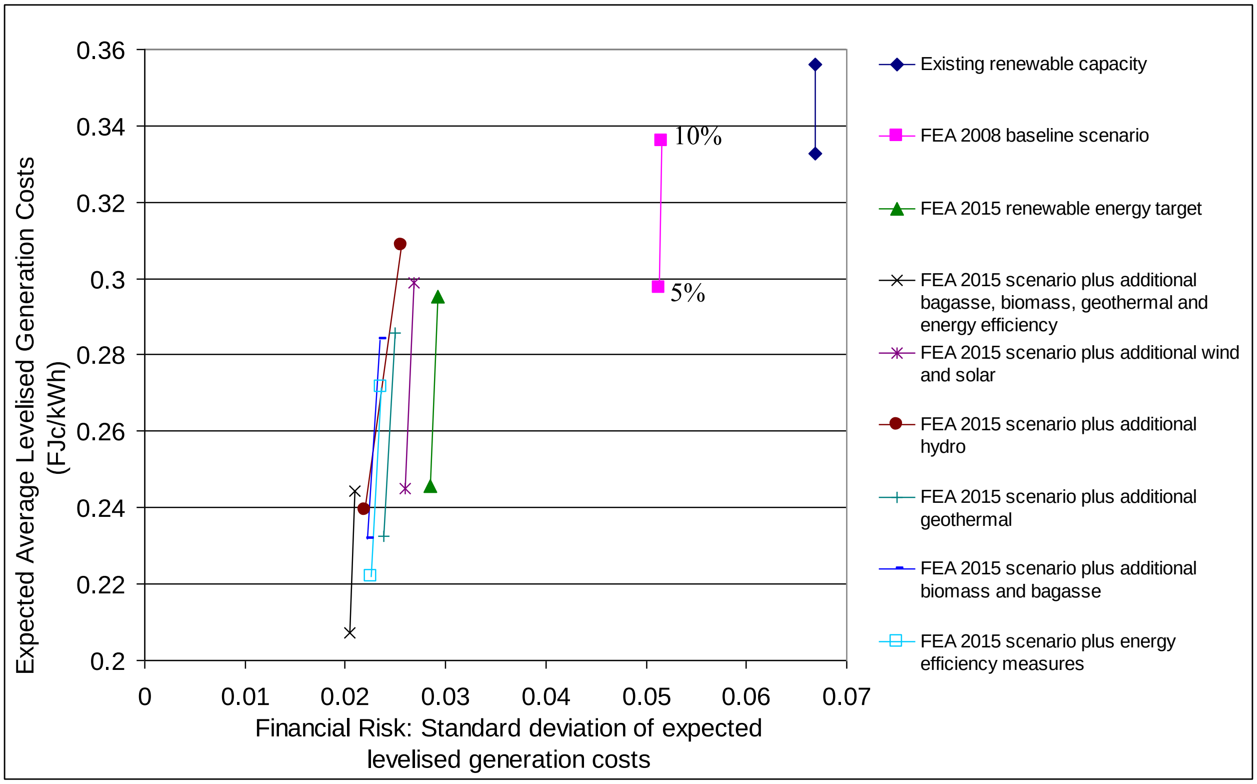
technologies described above when a 10 per cent discount rate is used. The fact that new hydro-power capacity will involve run-of-the-river schemes means that substantial back-up capacity in the form of oil-based generation will be required. This limits the benefits of new hydro-power investments. In the portfolio with additional hydro-power capacity, generation costs rise very modestly, while financial risk falls, but not to the same level as when there is investment in geothermal, biomass and bagasse, or energy efficiency. The same conclusions are supported by portfolios where renewable technology investment does not occur.

3.6.3 Sensitivity Analysis: Comparing a Five and Ten per cent Discount Rate

The impact of calculating levelised generation costs using a 5 instead of a 10 per cent discount rate is illustrated in figure 3.6.3a. The sensitivity analysis performed using a 5 per cent discount rate generally confirms the findings discussed in section 3.6.2. Investment in renewable technologies generally reduces portfolio generation costs and financial risk. This is especially true of low-cost, low-risk technologies such as energy efficiency, geothermal, biomass, and bagasse technologies.

The use of a 5 per cent discount rate favours technology portfolios with a higher share of renewable-based power generation. Portfolios with a high share of capital-intensive renewables, such as hydro-power and geothermal technologies, are subject to the biggest cost reductions. Risk also declines modestly in most portfolios, due to a reduction in the share of total costs comprising capital costs (which generally have a high financial risk). Again, the impact of this is most significant in portfolios with large amounts of capital-intensive renewable technologies.

Figure 3.6.3a Comparing Technology Portfolios using a 5 and 10 per cent Discount Rate



Investment in hydro-power, wind-power and solar-power is more attractive when a 5 per cent discount rate is used in place of a 10 per cent discount rate. Generation costs in both scenarios are lower than the FEA 2015 scenario. Portfolios with additional wind and solar-power nevertheless remain less attractive than those with the low-cost, low-risk renewables listed above. The portfolio with additional investment in hydro-power continues to have higher generation costs than portfolios with low-cost, low-risk renewables, although the difference in costs is reduced. However, the financial risk associated with the portfolio does decline to a level slightly lower than that of all but one of the other portfolios (that of the "best case" scenario).

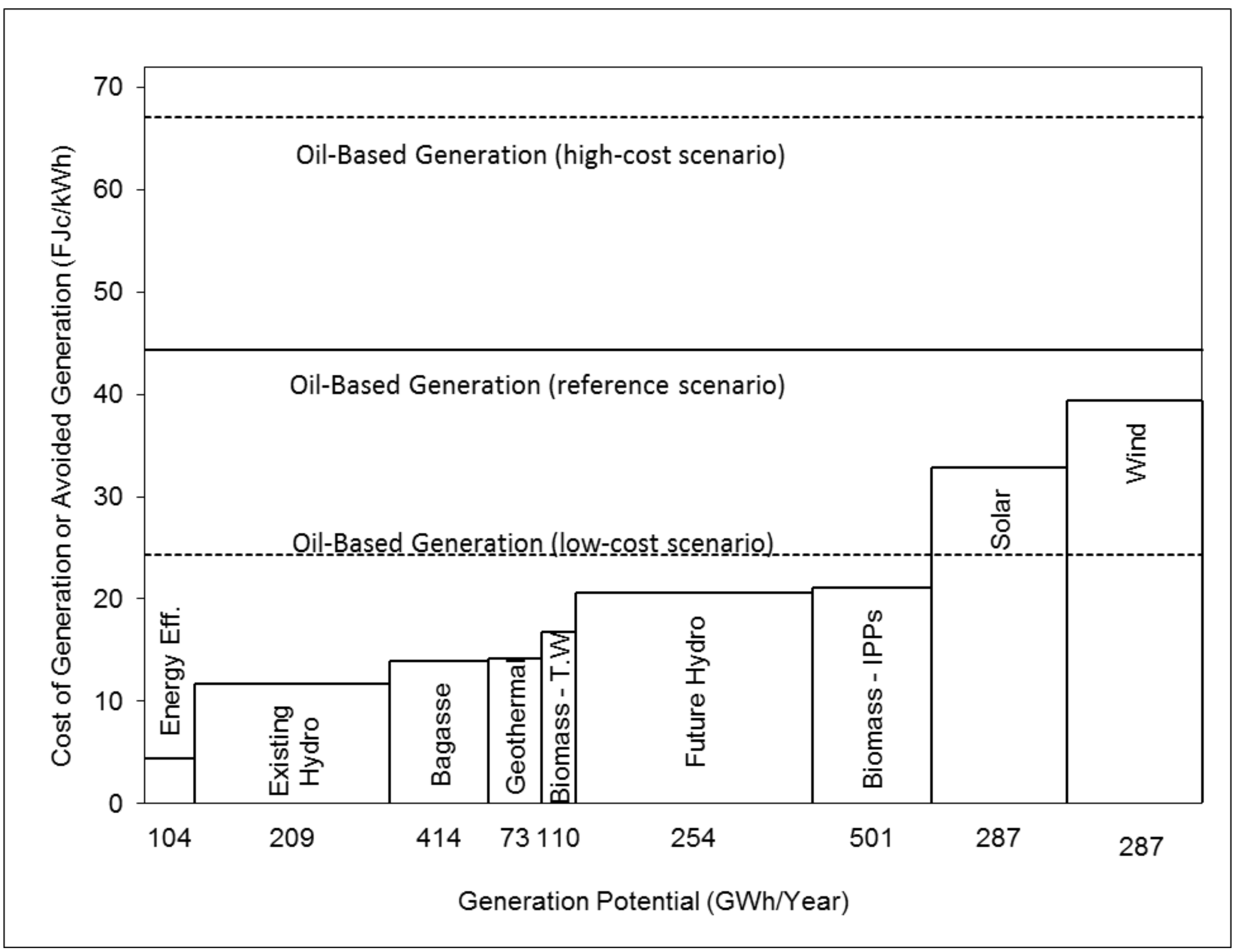
3.6.4 Sensitivity Analysis: Oil Price Variation

Oil prices are also varied in the model as part of a sensitivity analysis. The oil prices are based on the forecast oil price for 2025 contained in the Energy Information

Administration's (EIA) 2010 *Annual Energy Outlook*. The reference scenario of US$120 per barrel of oil has been used in the analysis so far. The EIA's low and high-price scenarios are very different. The low-price scenario is for an oil price of US$50 per barrel, which assumes increased competition and trade in oil around the world, high levels of investment, and increased production levels from OPEC. The high-price scenario is for an oil price of US$200 per barrel, which results from nationalisation of oil facilities, high rates of economic growth and oil consumption, and lower output from OPEC.

The impact of oil price variation on the technology cost curve is illustrated in figure 3.6.4a. The least-cost analysis shows that oil-based generation costs remain higher than those of renewable technologies in all scenarios, when assessed on a stand-alone basis, although not for high-cost technologies which are more expensive in the high-price scenario.

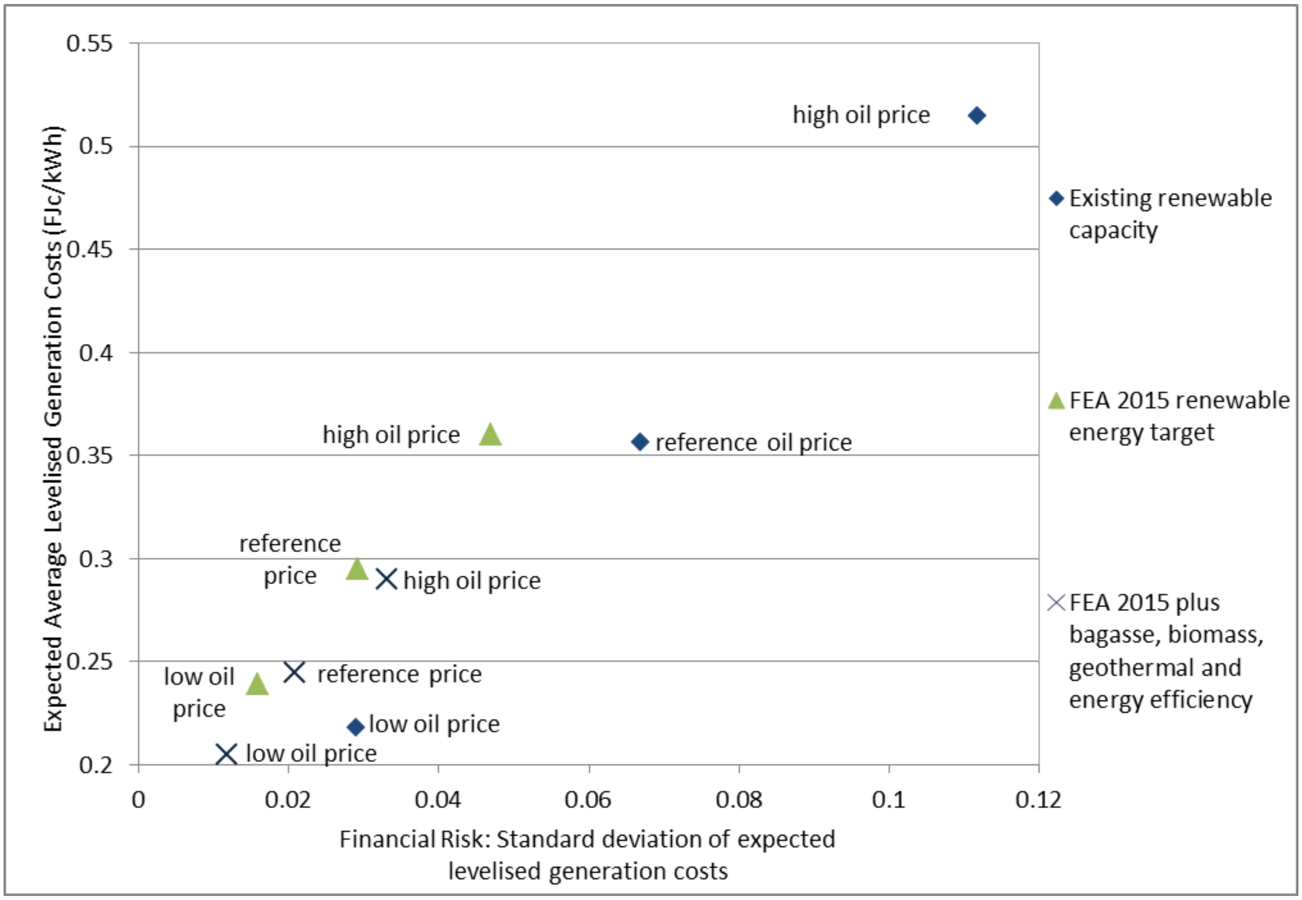
Figure 3.6.4a Technology Cost Curve with Different Oil Prices



Modelling results are illustrated in figure 3.6.4b for three technology portfolios: existing renewable capacity, the FEA 2015 renewable energy target, and the low-cost, low-risk portfolio involving additional investment in bagasse, biomass, geothermal and energy efficiency technologies. Expected generation costs and financial risk are lower across all three technology portfolios when the oil price is lower (and vice versa). However, the impact varies, being more significant where oil-based generation is more prevalent (such as the existing renewable energy portfolio). As a result, in the high-price scenario, expected generation costs and financial risk are significantly higher for the existing renewable energy portfolio. Renewable technology investments are therefore most justified where oil prices will be high in the future.

A low oil price in 2025 raises questions about some of the conclusions reached in the earlier analysis. In the low oil-price scenario, renewable energy technology portfolios continue to be associated with lower levels of financial risk than the portfolio with no further investment in renewable technologies (although the “risk mitigation” gains of renewable energy investments are lower). The same is not necessarily the case for generation costs. In the low-price scenario, the technology portfolio with the lowest generation costs continues to be that with considerable investment in low-cost, low-risk renewable technologies. However, the difference between it and the portfolio involving no additional investment in renewable technologies is very small. Interestingly, the FEA 2015 renewable energy target portfolio has higher expected generation costs than the existing renewable capacity portfolio where the future price of oil is low (although again, the difference is small).

Figure 3.6.4b Sensitivity Analysis: Oil price variation



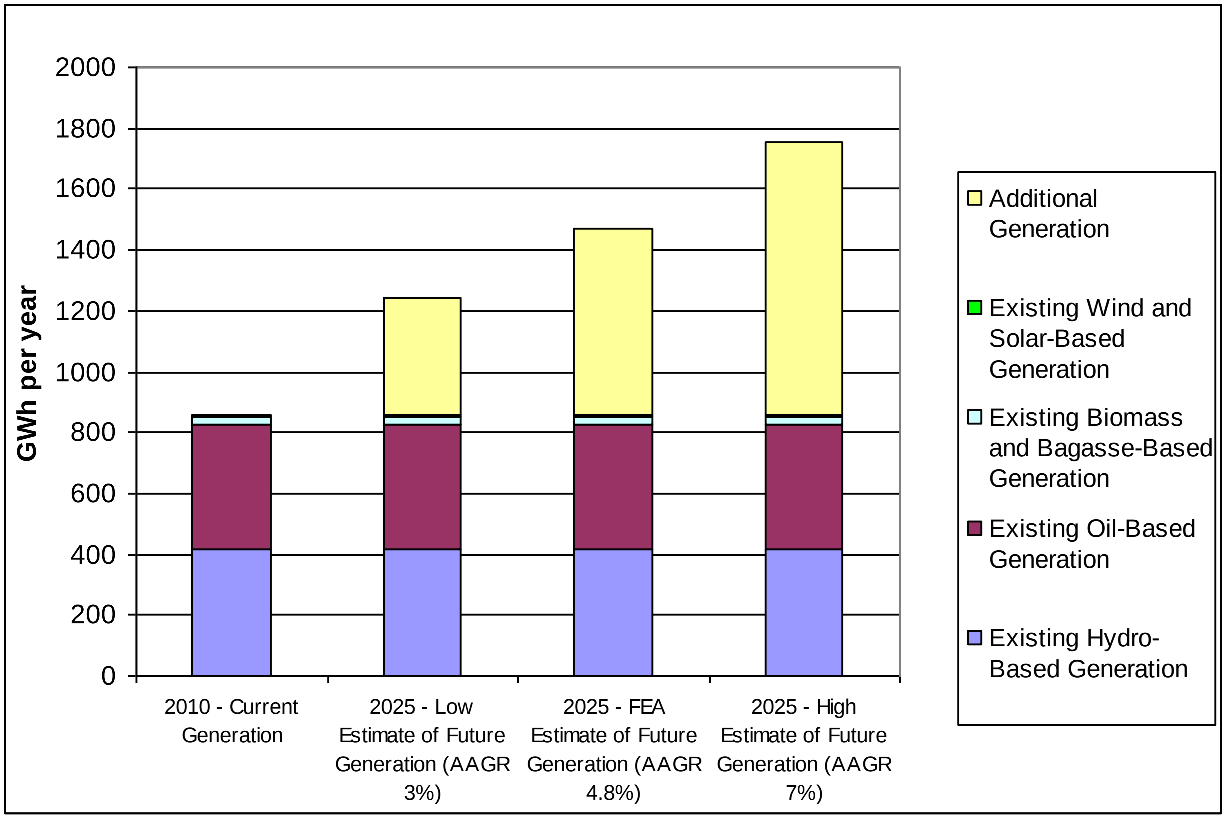
3.6.5 Sensitivity Analysis: The Impact of Changes in Total Demand

The model sets out two additional scenarios where total electricity generation varies compared to that forecast by the FEA. This enables an exploration of how changes in aggregate electricity demand affect expected average portfolio generation cost and financial risk. This is different to the energy efficiency measures described previously, as it refers to different scenarios of future demand for power, rather than specific measures that could be implemented to reduce demand (and that carry specific costs). The three scenarios shown in figure 3.6.4a are:

- The FEA forecast, where an average annual growth rate in electricity production of 4.8 per cent means that electricity generation in 2025 is 1,435 GWh per year;

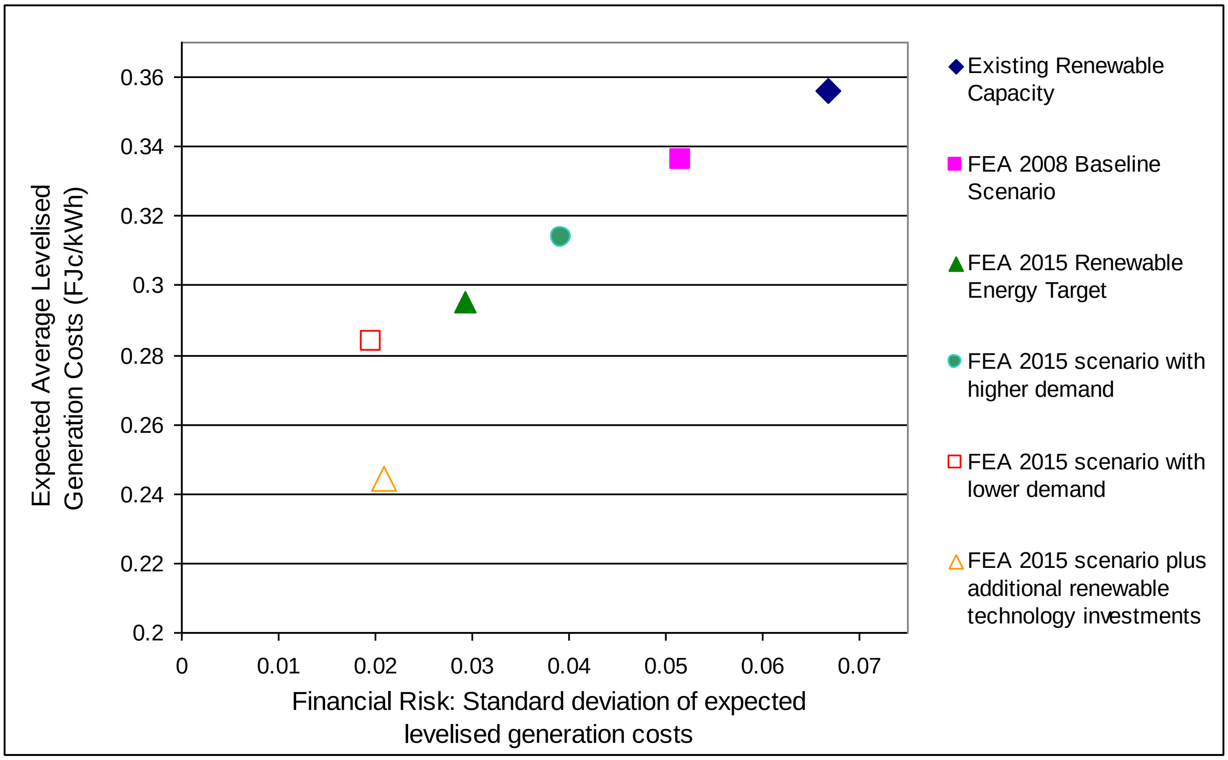
- A “high demand” scenario where an average annual growth rate in electricity production of 7 per cent, higher than that forecast by the FEA, results in electricity generation of 1,753 GWh per year in 2025; and
- A “low demand” scenario where an average annual growth rate in electricity production of 3 per cent, lower than that forecast by the FEA, means that electricity generation in 2025 is 1,240 GWh per year.

Figure 3.6.5a Current and Future Electricity Generation in the Fiji Grid



The cost and financial risk implications of these three scenarios are shown in figure 3.6.5b. All three scenarios assume investment in renewable technologies predicted by the FEA in its 2015 renewable energy target scenario. The two other reference scenarios and the “best case” FEA 2015 scenario with additional investment in low-cost, low-risk technologies are also included in the figure.

Figure 3.6.5b. Cost and Risk Implications of Changes in Electricity Production, 2025



The results show that, all other things being equal, lower aggregate electricity demand reduces average generation costs and financial risk. The reason for this is that lower total power production means less oil-based generation (which has high generation costs and financial risk). The opposite is true for the scenario where electricity demand is high: portfolio generation costs and financial risk in that scenario are higher than in the FEA 2015 renewable energy target scenario. As with investment in renewable technologies, differences between the portfolios are more marked with respect to financial risk than generation costs.

The results again highlight the economic benefits from reducing power consumption. These benefits suggest that government efforts to improve energy efficiency using a number of strategies are warranted, including introduction of labeling and MEPS, more rigorous building codes, reference to energy efficiency in the mandate of the Commerce Commission, and (for the Commerce Commission) consideration of time-of-day pricing.

Significantly, the results stress the importance of investment in renewable technologies commensurate with growth in electricity demand: as demand for power increases, so too must investment in renewable technologies if portfolio generation costs and risk are not to rise. This also raises longer term questions about what will occur when renewable energy potential from low-cost, low-risk technologies is exhausted, and demand for electricity is still growing.

3.6.5 Discussion

The modelling results indicate that investment in renewable technologies is beneficial from both a cost and energy security perspective. The issue of financial risk is particularly important. Investment in renewable technologies reduces expected average portfolio generation costs: from 35.6 FJc/kWh (for existing renewable generation capacity) to 29.5 FJc/kWh in the FEA 2015 scenario, and to 24.4 FJc/kWh in the "best case" portfolio with additional investment in low-cost, low-risk renewable technologies. Further reductions are not possible because of upper limits set for low-cost, low-risk generation technologies: namely energy efficiency, geothermal, biomass and bagasse. These upper limits are associated with limited renewable energy resource availability in Fiji (or assumed energy-saving options in the case of energy efficiency).

Relative reductions in financial risk associated with technology portfolios are greater still. Risk, as measured by the standard deviation of expected levelised average costs, declines from 0.067 to 0.029 standard deviations when moving from the no-action "existing renewable generation" scenario to the FEA 2015 scenario, and further to 0.021 in the technology portfolio with additional investments in energy efficiency, geothermal, biomass and bagasse technologies. This result indicates that investment in renewable energy technologies has significant advantages in terms of energy security for Fiji's electricity grid.

The modelling results were subject to a number of sensitivity analyses. The findings are confirmed when assumptions about future demand and discount rates are varied. The use of a 5 per cent discount rate in the modelling makes renewable technologies more attractive relative to oil-based generation, especially on the basis of generation costs. The costs of capital-intensive renewable technologies such as hydro, geothermal, wind and solar-power technologies decline most when a 5 per cent discount rate is used. Investment in renewable technologies becomes more important when future demand for electricity is higher than that forecast by the FEA. Higher levels of demand mean higher generation costs and greater financial risk if investment in renewable technologies does not increase.

The findings hold when the oil price is varied in most, but not all, cases. The modelling results in favour of investment in renewable technology are strengthened when a high oil price is assumed. The results are more complex when a low oil price is assumed. In a scenario where oil prices are low, the technology portfolio with the lowest expected generation cost and financial risk continues to be the portfolio with additional generation in low-cost, low-risk renewables. However, the advantages of this portfolio over others are not large. In the case of the FEA 2015 portfolio, expected generation costs are actually higher than the portfolio with no new investment in renewable technologies – although the difference is small.

A general conclusion from this sensitivity analysis is that the differences between portfolios narrow when oil prices are low. This highlights the risk-mitigation purpose of investments in renewable technologies. As a risk mitigation measure against oil price increases, investment in renewable technologies is most beneficial when the future price of oil is high. It is also worth highlighting that the high, reference, and low oil-price scenarios envisaged by the EIA are not of equal probability. The most likely scenario envisaged by the EIA is the reference scenario; the high and low price scenarios involve strong assumptions.

The modelling results point to several policy implications. The results generally support investment in renewable generation capacity that is forecast by the FEA, and especially investments in energy efficiency improvements. The FEA 2015 scenario has significantly lower generation costs than scenarios where no or minimal investment in renewable technologies occurs (as in the existing renewable generation capacity and the FEA 2008 baseline scenarios). Significant investments in renewable technologies are forecast by the FEA before 2015; however the likelihood of all investments proceeding is low. The FEA's goal of generating 90 per cent of electricity from renewable technologies by 2015 is therefore unlikely to be achieved.

Importantly, the modelling suggests that some investment in renewable generation capacity could be better directed. Investment in hydro-power is shown to have a minimal impact on portfolio generation costs due to the requirement for back-up capacity, even when calculated using a 5 per cent discount rate. Additional hydro-power capacity does reduce financial risk, although only to a similar extent as other low-cost, low-risk renewable technologies (when calculated using a 10 per cent discount rate). The analysis suggests that there should be greater consideration of investment in energy efficiency measures, and geothermal, biomass and bagasse technologies.

3.7 Conclusion

This chapter has analysed the cost and energy security implications of incorporating different renewable technologies in Fiji's electricity grid. The analysis gives an empirically grounded, quantitative perspective on current and planned investments in renewable technologies on the grounds of improving energy security and simultaneously lowering electricity generation costs.

The chapter has developed and applied a stochastic simulation model based on portfolio theory, which shows the impact of different renewable technologies on both expected portfolio generation costs and financial risk for scenarios of future electricity generation in Fiji in 2025. The results generally support investments in renewable technologies that are projected by the FEA. These investments were shown to reduce expected average generation costs in the Fiji grid to 29.5 FJckWh compared to 35.6 FJc/kWh if no extra investment in renewable technologies were to occur. The impact on financial risk, defined as the likelihood that actual costs will differ from expected costs in the future, is very significant. Financial risk declines from 0.667 to 0.029 standard deviations as a result of renewable technology investments. Technology portfolios with investment in renewable technologies therefore demonstrate considerably greater energy security than portfolios without such investment (given threats to energy security in Fiji's power grid are price-based, as outlined in chapter two).

The modelling results indicate that the implementation of energy efficiency measures together with additional investment in low-cost, low-risk renewable technologies, such as geothermal, biomass, and bagasse technologies, would further lower expected generation costs and financial risk in the electricity grid. Investment in high-cost renewable technologies such as wind and solar-power would reduce financial risk but increase expected average generation costs (or have no effect on costs, if a 5 per cent discount rate is used). Investment in hydro-power would also decrease financial risk for the portfolio but would have a minimal impact on expected generation costs.

The modeling results generally withstand sensitivity analyses, although not in all cases. The adoption of a five per cent discount rate strengthens the case for investment in renewable technologies. So does the use of a high oil price. The benefits of investment in renewable technologies are less clear when a low oil price is assumed. The best case portfolio remains the most attractive; however its advantage over a portfolio with no investment in renewable technologies is not large. The benefits of other investments in renewable technologies (such as in the FEA 2015 scenario) disappears for the most part under a low oil price. This demonstrates that investments in renewable technologies are beneficial from a cost and risk perspective in most, but not all, circumstances.

Changes in demand for electricity also have an impact on portfolio generation costs and financial risk. Demand for electricity higher than that forecast by the FEA means higher portfolio generation costs and financial risk, assuming the same level of investment in renewable technologies. Lower demand for power means the opposite: portfolio generation costs and financial risk are lower than envisaged. This highlights the importance of investment in renewable technologies commensurate with growth in electricity demand. Further research is required in this area. The model only incorporates a subset of measures that could improve energy efficiency, given limited data. It is therefore likely that the cost and risk gains from measures to improve energy efficiency are larger than stated in the model.

The results point to several policy implications. First, they suggest that the government should be encouraging further investment in renewable technologies on energy security grounds, and with the goal of lowering expected generation costs. Second, the results suggest that the FEA should consider investment in these low-cost, low-risk technologies against planned investment in hydro-power generation capacity. Energy efficiency, geothermal, biomass and bagasse technologies lower portfolio generation costs to a greater extent than hydro-power technology, and have a similar impact on financial risk. This is due largely to the back-up capacity required for run-of-the-river hydro-power schemes, which makes new hydro-based power generation more expensive.

These findings raise several questions for policy makers. Is investment in low-cost, low-risk technologies being encouraged? Why is the FEA currently focusing on investment in hydro-power but not energy efficiency, geothermal, biomass or bagasse technologies? Could more be done to facilitate investment in low-cost, low-risk technologies? These issues are explored in chapters four and seven.

Chapter 4

Institutional Arrangements for Grid-Based Electricity Generation

This chapter assesses the impact of institutional arrangements in the electricity grid on renewable technology investments. The FEA has pursued significant investments in renewable technologies as a result of commercial and non-commercial obligations set by government, although these investments have centred on hydro-power technology. Reform of the tariff determination process in the last six years has facilitated these investments, and is set to motivate investment in other renewable technologies by Independent Power Producers. Reform of the electricity sector in Fiji can therefore be considered a success in terms of encouraging renewable technology investment, despite its slow progress and a number of policy reversals. Further reform of the power sector has recently been announced, but is yet to be implemented. This chapter argues that these more recent reforms, including the partial privatisation of the FEA, are primarily designed to raise revenue and are unlikely to dramatically change FEA objectives or investments in renewable technologies. It also argues that there are limits to the feasibility of further liberalisation of Fiji's power sector given its small scale and existing regulatory capacity.

4.1 Introduction

This chapter assesses the impact of institutional arrangements in the electricity sector on grid-based renewable technology investments.[63] Institutional arrangements influence investment decisions in several ways, including through their impact on the incentives and revenue of power utilities. The analysis builds on chapter three, which demonstrated that renewable technologies could improve energy security in Fiji's electricity grid by reducing financial risk and lowering electricity generation costs. The portfolio modelling presented in chapter three showed that renewable technology investments forecast by the FEA are warranted, although it questioned FEA prioritisation of hydro-power investment. It also

[63] Discussion of regulation in the electricity sector in this chapter refers only to regulation of the electricity grid, not rural electrification policy.

demonstrated that additional investments in low-cost, low-risk technologies such as energy efficiency, geothermal, biomass and bagasse technologies, could be economically beneficial. This chapter examines whether additional investment in renewable technologies (including low-cost, low-risk technologies) are likely to occur, given the current institutional environment in Fiji. The central question addressed here builds on that of chapter three, that is, to what extent can renewable technologies improve security of supply in the electricity grid, given the regulatory framework governing electricity provision and its impact on risk aversion and capital investment?

The Institutional Analysis and Development (IAD) framework introduced in chapter two is used to examine institutional arrangements in the electricity sector. The analysis explores the relevant action situations, including physical conditions, rules-in-use, and attributes of actors. This context is used to examine patterns of interaction and the incentives of stakeholders. The analysis is divided into two levels: the operational and policy levels. At the operational level, the primary question is how institutional arrangements affect investment decisions in Fiji's electricity grid. The focus is on current and forecast renewable technology investment in the Fiji grid. Answering this question involves an original exploration of the impact of institutional arrangements on the incentives and risk aversion of stakeholders. The tariff setting process and revenue of the FEA are particularly important in this respect.

At the policy level, the chapter examines the reasons that existing institutional arrangements are in place in the electricity grid, and the scope for future regulatory reform. This analysis is innovative in drawing together the history of public enterprise reform in Fiji, the physical features of Fiji's electricity grids, and international trends in power sector regulation in order to explain reform in Fiji's electricity sector. It shows that there are limits to the institutional arrangements and reforms that are feasible in Fiji. The section also provides the first comprehensive publicly available study of electricity sector regulation in Fiji since the announcement of reforms by the interim military government. This helps set the context for the discussion of policy implications in chapter seven.

4.2 Generation and Investment by the FEA: The Operational Level

4.2.1 Action Arena: Actors and the Action Situation

Electricity sector investment in the Fiji grid occurs in a broad action arena. The action arena can be broken into a number of action situations, which include investment, electricity tariff determination, and operation and maintenance. These action situations are located at the national level, with discussion of grid-based power supply focusing on national level actors as a result. Action situations are interrelated. For example, tariffs in Fiji are set at a rate that provides the FEA with a "reasonable return" on its capital investment, meaning that FEA investment in generation equipment influences tariff determinations (Commerce Commission 2010d: 2). At the same time, tariff rates are an important determinant of the FEA's ability to undertake investment. They also influence operation and maintenance of the FEA grid.

The FEA, as the state-owned monopoly provider of electricity in Fiji, has primary responsibility for investment decisions in, and operation and maintenance of, the electricity grid. Cabinet and the Minister for Works, Transport and Public Utilities influence these decisions. Important also are the central ministries, particularly the Ministry of Finance, Ministry of National Planning, and the Ministry of Public Enterprises, which provide advice to the cabinet when reviewing FEA planning (Interview with Ministry of National Planning, August 2009; Maunsell Limited 2005). In recent years, private and public sector companies have begun to play an increasing role in generation for the FEA grid, through joint ventures and as Independent Power Producers. Financiers and donors also potentially influence investment in the FEA grid.

The Commerce Commission is responsible for setting electricity tariffs, as an independent multi-sector regulator established under the *Commerce Commission Decree (2010)*.[64] In practice, the Commerce Commission relies heavily on submissions from the FEA to calculate appropriate electricity tariffs (Commerce Commission 2009; Commerce

[64] This replaces the *Commerce Act (1998)*.

Commission 2010b; Maunsell Limited 2005; Reddy 2010). Other lobby groups such as the Consumer Council of Fiji are not very influential, as they lack generation cost data, which is confidential under the relevant legislation (making it difficult to prepare informed submissions) (Interviews with Consumer Council of Fiji, July 2010; Baselala 2010d; Consumer Council of Fiji 2006; Fiji Daily Post 2008; Prasad 2009; Rina 2010c).[65] Independent Power Producers influence decision making in relation to feed-in tariffs (Interview with Fiji Sugar Corporation, Tropik Wood and Seamech, August 2009).

4.2.2 Influences on the Action Arena (or Context): Physical Conditions, Attributes of Community and Rules-in-Use

Physical Conditions

The economic and population profile of Fiji establishes demand for electricity and the FEA's service area. Energy resource availability in Fiji establishes the economic and technical feasibility of generation from different technologies, as does the state of technology. Fiji is fortunate compared to other Pacific island countries in this respect, with a range of renewable technologies that could be used to generate electricity at low cost. This is the result of both natural resource availability and the presence of industry in Fiji, which for instance enables power generation from biomass and bagasse. The size of the FEA grid also has an impact on the feasibility of technologies. Large-scale gas or coal generation is not feasible in such a small system. This makes renewable technologies a low-cost means of electricity generation.

[65] This lack of transparency has led to complaints by the Consumer Council of Fiji, which questions why cost information for a monopoly government owned company needs to remain confidential (Interviews with Consumer Council of Fiji, July 2010; Baselala 2010d; Consumer Council of Fiji 2006; Fiji Daily Post 2008; Prasad 2009; Rina 2010c).

This section discusses the attributes of actors in the electricity sector. This includes analysis of their history, features, roles and functions. A more in-depth examination of the rules-in-use that are pertinent to the FEA follows.

The Fiji Electricity Authority

The FEA is a publicly owned Commercial Statutory Authority. Public enterprises are common in Fiji, holding 16–25 per cent of total fixed assets in the economy (ADB 2010).[66] Successive governments have sought to make public enterprises commercially oriented and financially viable under the *Public Enterprise Act (1996)*. The Act seeks to corporatise public enterprises, and states that their primary goal should become one of operating: "as a successful business and, to this end, to be as profitable and efficient as comparable businesses which are not owned by the State" (Public Enterprise Act, 1996, Schedule 1, Section 10). The reforms have achieved mixed results. The Minister for Public Enterprises has set as a target for public enterprises a return on capital of 10 per cent by 2011 (Government of Fiji 2010b). Almost no public enterprise currently meets this target. Indeed, from 2002 to 2006, the average return on equity of public enterprises in Fiji was -0.7 per cent (ADB 2010). There are few consequences for managers as a result of these poor outcomes (Sarker and Pathak 2003). The FEA has performed better than the average. It has been profitable since 1990, with the exceptions of 2000 and 2004-06, but has nonetheless failed to achieve the 10 per cent return on capital established by Government (FEA 2000; FEA 2001; FEA 2002; FEA 2003; FEA 2004; FEA 2005; FEA 2006; FEA 2007a; FEA 2008a; FEA 2009a; FEA 2010; Rika 2009).

The *Public Enterprise Act (1996)* also seeks to remove government interference in the operation and management of public enterprises. Section 83 states that: "a Commercial Statutory Authority and its board are not subject to direction by or on behalf of the government". The extent to which this independence exists in practice depends on the

[66] The term "public enterprise" can be used interchangeably with the term "state-owned enterprise". In Fiji, "public enterprise" is more commonly used. This thesis refers to "public enterprises" in a Fijian context, and uses the term "state-owned enterprise" when discussion is more general.

organisation. In the case of the FEA, day-to-day operations are left to the discretion of FEA management. The Major Projects and Strategy Group within the FEA gives management advice and is the only group in Fiji with the appropriate software for planning of power sector expansion (Maunsell Limited 2005). Large projects such as the Nadarivatu hydro-power scheme are an exception as they have macroeconomic implications. The Government of Fiji is therefore involved in their design and approval. The Minister for Works, Transport and Public Utilities also appoints the FEA board; although this decision is in practice made with the consensus of cabinet. Independence from government is therefore rather less pronounced than suggested by the *Public Enterprise Act (1996)*.

Reform of the FEA has been attempted in the past but has achieved mixed results, as outlined in section 4.3.3. A progressive Board of Directors with significant private sector experience reduced costs and cut staffing levels in the early 2000's, improving efficiency as a result. Appropriate operation and maintenance of an electricity system has historically been an issue in developing countries, and has adversely affected energy security (Besant-Jones 2006; Choynowski 2004; Gratwick and Eberhard 2008). The same problems have not affected the FEA, which has performed well compared to utilities in other SIDS and developing countries, especially in the last decade (Maunsell Limited 2005; World Bank 2006a). This is due to adequate tariff rates, good management and human resources, and a regulatory system that provides FEA management with incentives to ensure sound operation and maintenance of its equipment. It is also partly the result of contracting out certain operations to reputable private sector companies (Maunsell Limited 2005).

In May 2010, the interim government announced new reforms of the FEA. This followed several years of discussion about reform, and light-handed regulation of the FEA (Interviews with Department of Energy, Ministry of National Planning, July and August 2009).[67] The reforms announced by the government mean that the FEA will be partially privatised, with up to 49 per cent of the company sold to investors. Regulatory and pricing functions will also be moved to other government organisations, as has already occurred with tariff determination. This is discussed in section 4.3.3.

[67] For example, many regulatory functions have been handled by the FEA itself, including the licensing and sale of electricity by Independent Power Producers (Maunsell Limited 2005).

Independent Power Producers

The two main Independent Power Producers (IPPs) currently operating in Fiji are Tropik Wood and the Fiji Sugar Corporation (FSC). These companies are public enterprises and currently produce 2 per cent of the electricity in the FEA grid. They are important because of the potential for producing low-cost, low-risk electricity from bagasse and biomass (described in chapter three). Both companies are investing in renewable technologies for financial reasons. In the sugar industry, mills need to sell excess power to the grid in order to remain competitive (Interview with FSC, August 2009). In the timber industry, woodchip waste can be burned to produce power, thereby both disposing of the waste and generating revenue for Tropik Wood (Interview with Tropik Wood, August 2009).

Investment by IPPs has been limited in Fiji in the past, due to the low feed-in tariffs negotiated by the FEA. This situation has changed in recent years, as described in section 4.2.3.[68] A number of new IPPs have signed Power Purchase Agreements (PPAs) with the FEA as a result. The projects that are most advanced are the Vuda and Labasa biomass plants. Both involve investment by foreign energy companies, and will require the planting of crops for biomass fuel.

The biggest potential barrier to expansion of electricity supply from IPPs is in the sugar industry. The production of electricity from bagasse relies on the continuing supply and processing of sugar cane in Fiji. This is not guaranteed. The FSC has faced financial difficulties for over a decade (Mahadevan 2009b; Prasad 2010; Prasad and Narayan 2008; Snell and Prasad 2001; White 2003). Inefficiencies in its mill operations have led to protests from farmers and recently a military intervention in which soldiers were placed in mills to increase production and prevent political in-fighting (Chaudhary 2010a; Chaudhary 2010c). Prasad (2010: 14) notes that efficiency in Fiji's mills has decreased in the last 20 years, with the amount of sugar cane required to produce a tonne of sugar rising from 8-9 tonnes prior to 1990 to 13.6 tonnes in 2009. Power generation has also declined, and generation equipment has not been upgraded (Prasad 2003; Singh 2009). At the same time,

[68] FSC previously attempted to circumvent this problem by exploring the possibility of selling power directly to the Vatukoula Gold Mine (at a rate substantially higher than the feed-in tariff). It was stopped by the *Electricity Act (1966)*, which prevents direct third party sales of electricity in areas where the FEA grid extends (Interview with Fiji Sugar Corporation, August 2009).

the European Union has progressively reduced preferential access to European markets for Fijian sugar exports (as outlined in chapter one). The result has been consistent annual losses by the FSC. In 2010, operating losses amounted to FJ$25 million compared to revenue of FJ$195 million (Fiji Sugar Corporation 2010). The production of sugar cane has also decreased, largely as a result of the expiry of land leases and migration of Indo-Fijians to urban areas (Mahadevan 2009b; Prasad 2010; Prasad and Narayan 2008).

The Government of Fiji has responded to the crisis by injecting capital into the FSC in order to prevent its bankruptcy. Beginning in 2011, it will directly fund FSC operations and debt repayments, at an estimated annual cost of approximately FJ$110 million (Government of Fiji 2010a). This decision follows an earlier failed attempt by FSC management to improve mill efficiency and increase power production using a loan from Exim Bank of India (Fiji Sugar Corporation 2009; Government of Fiji 2010a; Mahadevan 2009b; Prasad and Narayan 2008).

The future of the sugar industry in Fiji nevertheless remains uncertain. It survives due to government support, and at a large cost to the Fijian taxpayer. At the same time, it is difficult to envisage the government allowing the industry to collapse. Exports of sugar comprise almost 6 per cent of Fiji's GDP (down from approximately 12 per cent in 1996) and over 20 per cent of total merchandise exports (Fiji Islands Bureau of Statistics 2011b; Prasad 2010). The macroeconomic impact of the industry's collapse would be significant. More important still, it is estimated that 200,000 Fijians, or 24 per cent of the population, rely on the industry for their livelihoods in some way (Government of Fiji 2010a; Mahadevan 2009a; Mahadevan 2009b; Narayan and Prasad 2003; Prasad and Narayan 2008). Its collapse would therefore result in large-scale migration to urban areas with concomitant social problems. The analysis in chapter three therefore assumes in most portfolios that sugar production will continue in 2025.

Government of Fiji

The Government of Fiji has the power to significantly influence FEA investment under existing regulatory arrangements, and is involved in the electricity sector in various ways (as illustrated in figure 4.2.2a). Cabinet's appointment of the FEA board was mentioned previously.[69] The Annual Corporate Plan and Statement of Corporate Intent are also reviewed by cabinet (Interview with Ministry of National Planning, July 2009). The Statement of Corporate Intent summarises the Annual Corporate Plan, and includes details on:

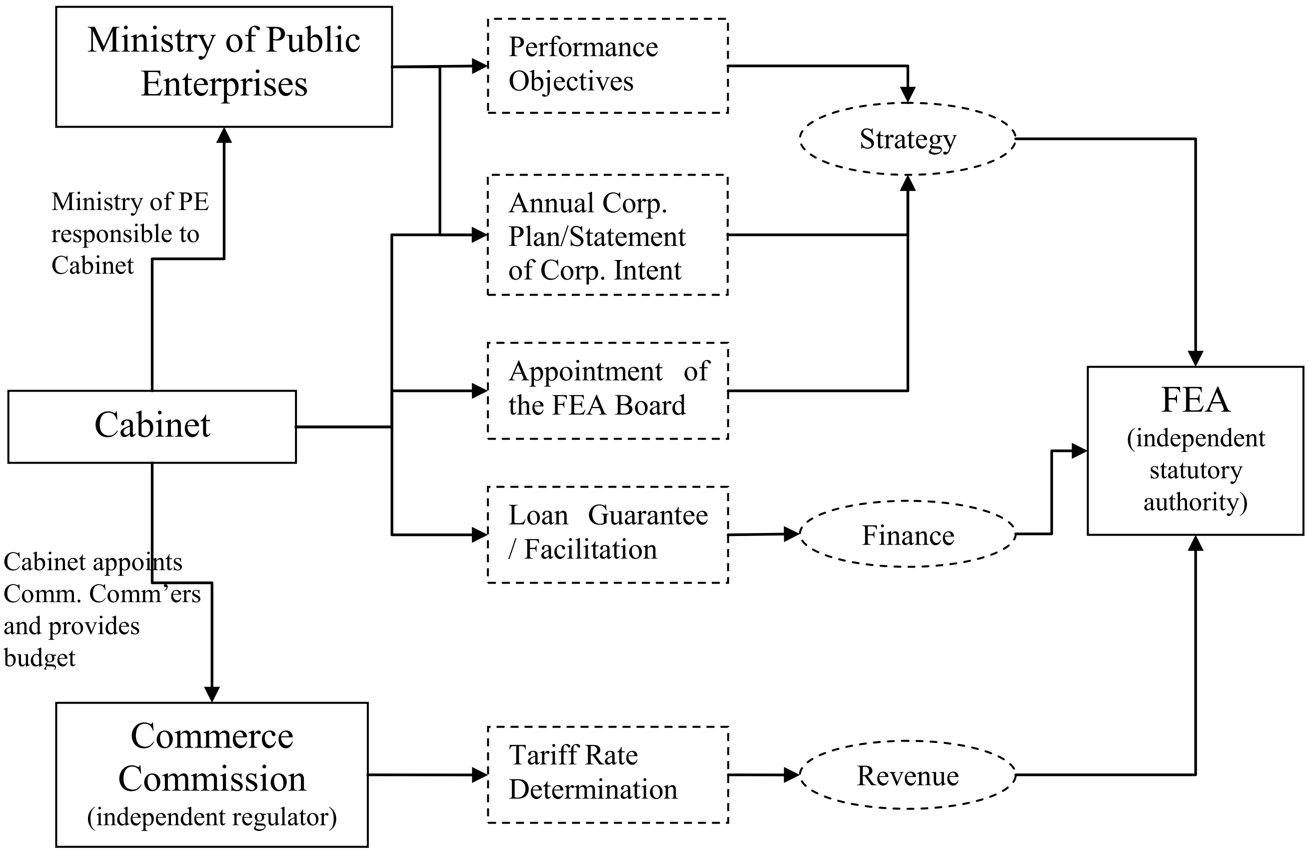
- FEA objectives;
- The nature and scope of the activities to be undertaken by the FEA;
- Proposed borrowing; and
- Financial and non-financial performance targets.

This process potentially gives the government enormous power over FEA activities. The *Public Enterprise Act (1996)* states that changes can be requested where the relevant ministers do not agree with the plans of the FEA. This power is however rarely exercised. Indeed, it is clear from past FEA comments that there has been little government intervention in power sector planning (Maunsell Limited 2005).

Government is more involved in setting broad financial and non-financial targets for the FEA. These performance indicators are prepared jointly by the FEA and the Ministry for Public Enterprises (FEA 2009a). In 2010, they included a return on shareholder funds of 2.5 per cent, and oil-based generation of less than 45 per cent of total generation. In 2009, performance indicators included signature of a PPA with an IPP.

[69] In addition, the FEA board has in the past included representatives from the Department of Energy, Ministry of Finance and National Planning (which were previously one ministry) and the Ministry of Public Enterprise. This is no longer the case (Interviews with Department of Energy management, July 2009).

Figure 4.2.2a Government involvement in the Electricity Sector



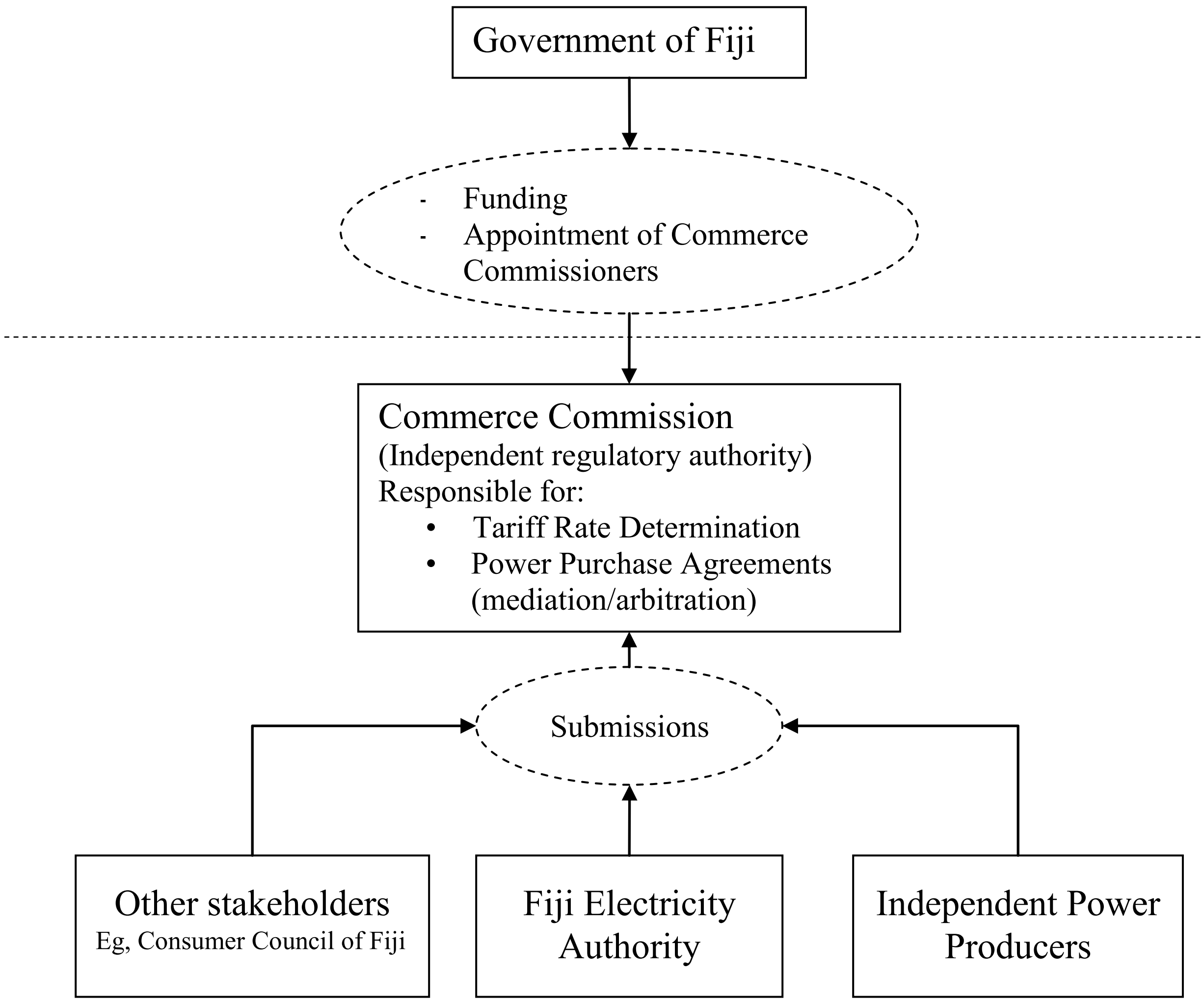
The government is also involved in power sector planning through its role in facilitating financing of major projects. Particularly important is government provision of debt guarantees, which facilitate FEA access to concessional finance. This role has become more important since the military came to power in 2006, with many traditional donors unwilling to lend to Fiji. In the case of the Nadarivatu hydro-power scheme, finance from China was sought and negotiated by the interim Prime Minister and senior ministers. The central ministries of finance and national planning were also involved in facilitating these negotiations, as was the Reserve Bank of Fiji (FEA 2009a).

The Commerce Commission

The Commerce Commission is responsible for determining electricity tariffs in Fiji, as illustrated in figure 4.2.2b. Tariffs are important in this discussion as they have an impact on the incentives of the FEA and other IPPs, ultimately affecting electricity sector investment. The Commerce Commission is a multi-sector regulator that determines prices and access rights in a number of monopolistic industries, including the electricity sector.[70] The Commerce Commission became active in relation to electricity tariffs in 2002, when it successfully lobbied the government to designate tariffs a "controlled price" under the *Commerce Act (1998)*. It did not actually change tariffs until 2005. Prior to this, electricity tariffs had remained constant for 13 years, shielded from cost pressures due to spare capacity and low costs at the Monasavu hydro-power scheme.

[70] It also sets prices for other "regulated good and services" identified by a Cabinet Minister (Commerce Act, 1998; Commerce Commission Decree, 2010).

Figure 4.2.2b Tariff Determination in Fiji's Electricity Sector (under the 2010 *Commerce Commission Decree*)



The Commerce Commission raised tariffs in 2005 on the grounds that there was no longer spare capacity at the Monasavu scheme, the FEA needed capital to further expand generation capacity, and fuel prices were rising. Tariffs increased gradually between 2005 and 2008, with an increase of 15 per cent being awarded in 2009 (Chaudhry 2010; Commerce Commission 2009; Commerce Commission 2010b; Commerce Commission 2010c; Commerce Commission 2010d). The Commerce Commission also implemented a fuel surcharge that temporarily increased average electricity tariffs by another 30 per cent between September 2006 and March 2009. Tariffs increased significantly in 2010. In June 2010, the Commerce Commission increased the average weighted tariff by 8.37 FJc/kWh, or 34 per cent. Soon after, another two-stage increase was implemented, raising the average weighted tariff from 33 FJc/kWh to 39.40 FJc/kWh (or another 19.4 per cent).[71] These tariff movements are shown in table 4.2.2a.

Table 4.2.2a Tariff Rates in Fiji, 2005-2011

<table>
<tr><th></th><th>Average Weighted Tariff (excl. surcharge) (FJc/kWh)</th><th>Fuel Surcharge (FJc/kWh)</th><th>Effective Average Weighted Tariff (FJc/kWh)</th></tr>
<tr><td>2005</td><td>19.48</td><td>n/a</td><td>19.48</td></tr>
<tr><td>2006</td><td rowspan="2">20.13</td><td>n/a</td><td>20.13</td></tr>
<tr><td>Sept 2006</td><td rowspan="2">6.51</td><td>26.63</td></tr>
<tr><td>2007</td><td rowspan="2">20.77</td><td>27.28</td></tr>
<tr><td>June 2008</td><td>5.53</td><td>26.30</td></tr>
<tr><td>March 2009</td><td>21.41</td><td>n/a</td><td>21.41</td></tr>
<tr><td>Sept 2009</td><td>24.63</td><td>n/a</td><td>24.63</td></tr>
<tr><td>June 2010</td><td>33.00</td><td>n/a</td><td>33.00</td></tr>
<tr><td>Oct 2010</td><td>39.40</td><td>n/a</td><td>39.40</td></tr>
<tr><td>Total increase (2005-2011)</td><td>19.92 (102 per cent)</td><td></td><td>19.92 (102 per cent)</td></tr>
</table>

The Commerce Commission is notionally independent from government, as established under the *Commerce Commission Decree (2010)*. However the true independence of the Commerce Commission has been challenged in the past. A 2005 consultancy report stated that there was a "widespread perception" that the tariff set by the Commerce Commission was influenced by government; a claim rejected by the Commerce Commission (Maunsell Limited 2005: 36-7). In comments to the consultant, the FEA also said that it was doubtful that the Commerce Commission had the "economic and power engineering analytical capability to analyse the network for tariff studies" (Maunsell Limited 2005: 126).

[71] Eligibility for the lifeline tariff of 17.2 FJc/kWh was also tightened, with consumption criteria declining from 75 to 130 kWh per month. The government in 2010 announced that the FEA will be reimbursed for providing this lifeline tariff for the first time. The FEA will receive FJ$3.5 million annually from government (Commerce Commission 2010c; Government of Fiji 2010a). This increases the commercial orientation of the FEA by moving responsibility for social objectives to the government.

Government interference in setting electricity tariffs was clearly visible in 2008, when oil prices peaked. In response to soaring costs of production, the Commerce Commission increased the fuel surcharge that the FEA could charge its customers for electricity. This change was promptly rejected by the interim Minister for Finance on the grounds it would have a negative impact on customers facing cost of living pressures as a result of high food and fuel prices (Chaudhry 2010; FEA 2008a). Subsequent submissions by the FEA for tariff increases were sent to both the Commerce Commission and the interim Minister for Finance, despite claims by the Commerce Commission that this was unnecessary (Interviews with Commerce Commission, August 2009; Government of Fiji 2009).

Despite this, the power of the Commerce Commission does appear to have increased in recent years. It has taken an aggressive stance towards industries displaying monopoly pricing, including hardware and telecommunications (Baselala 2010b; Baselala 2010c; Rina 2010b). The Commerce Commission has also developed as an institution and grown in size to over 60 people in 2010 (Commerce Commission 2010a; Reddy 2010).[72]

The powers of the Commerce Commission were strengthened in 2010, when the interim government issued the *Commerce Commission Decree (2010)*.[73] The *Commerce Commission Decree (2010)* clarifies the distinct roles of the Commerce Commission and the relevant Minister, stating clearly for the first time that the Commerce Commission has the power to set prices in the electricity sector.[74] This is a step in the direction of regulatory independence. Continued non-interference by government in the tariff determination process should further increase confidence among stakeholders that tariff determination is apolitical. This is likely to facilitate investment in the electricity sector, as tariffs are more commonly set at an appropriate rate when the tariff determination process is apolitical

[72] At the same time, commissioners in the Commerce Commission continue to be appointed by the relevant minister, and the commission depends on government for about 95 per cent of its budget (5 per cent is collected through fees the Commerce Commission charges industries that it regulates) (Reddy 2010).

[73] A Cabinet decision in 2004 (557/2004) also expanded the powers of the Commerce Commission to include many formerly exercised by the Department of Fair Trading and the Prices and Incomes Board. This had limited impact on grid-based electricity generation.

[74] The *Commerce Act (1998)* had previously stated that the Minister was to make an order controlling prices in an industry, but was unclear about whether the Minister or the Commerce Commission then set prices. It was this lack of clarity that led the interim Minister for Finance to reverse the Commerce Commission deliberation on fuel surcharges in 2008.

(given that an independent regulator does not face the same political pressures as elected governments).

Rules-in-Use

Rules in Fiji's electricity sector are based around an evolving legislative framework. However, the roles and responsibilities of different organisations within this framework are sometimes unclear. For the FEA, an ongoing issue is the existence of multiple financial and social objectives (Maunsell Limited 2005; Interviews with Department of Energy management, August 2009). This is commonly acknowledged as a problem for state-owned enterprises (Ostrom, et al. 2001; World Bank 2006a). The failure of government to prioritise multiple and sometimes conflicting objectives can lead to inefficiencies and makes assessing the performance of management difficult.

The FEA has a number of objectives:

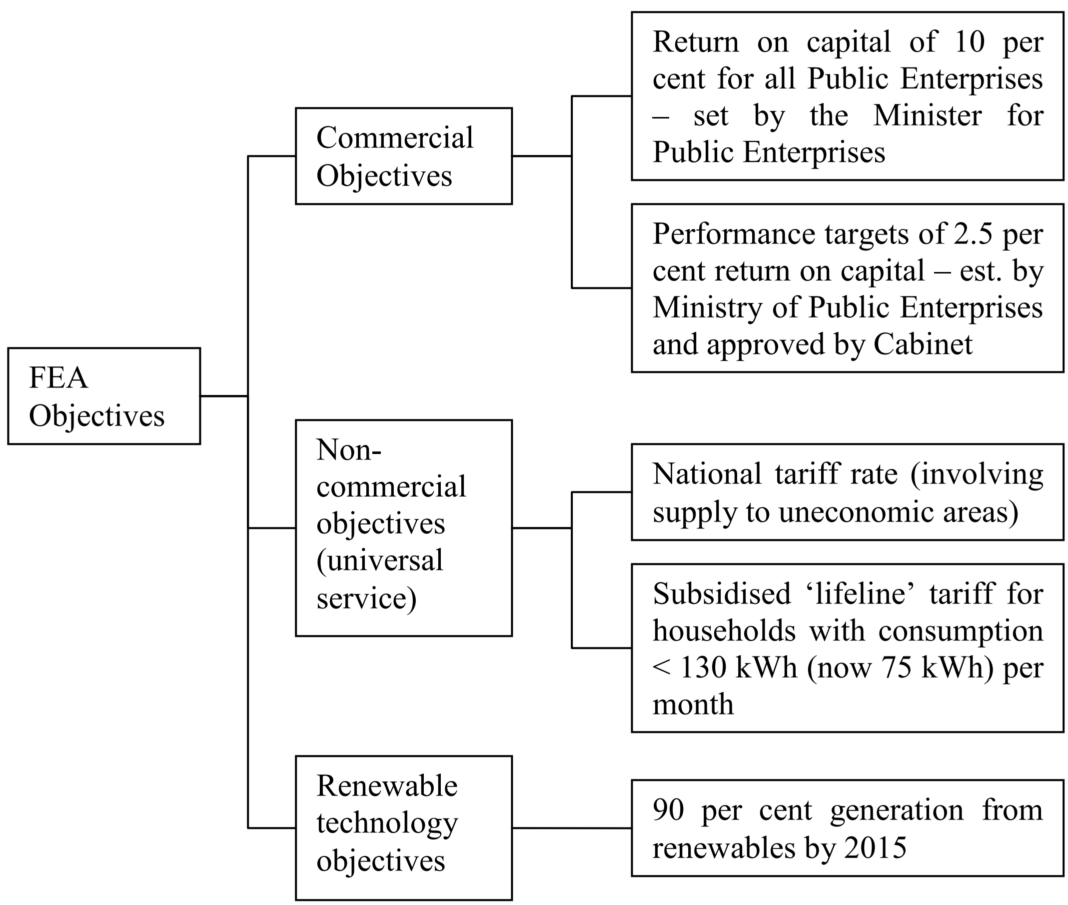
- Commercial objectives – These include a return on capital of 10 per cent by 2011, established by government under powers outlined in the *Public Enterprise Act (1996)*, and annual performance targets given to the FEA each year by the Ministry of Public Enterprises (FEA 2008a; FEA 2009a; FEA 2010; Government of Fiji 2010b).
- Non-commercial obligations – The *Electricity Act (1966)* requires that the FEA supply electricity to all areas of the FEA grid. The uniform electricity tariff imposed by the Commerce Commission means that the FEA must provide electricity at a loss in areas where the cost of supply is higher than the tariffs it receives. The uniform tariff therefore involves a cross subsidisation of electricity consumption: households in the Suva area pay tariffs that are higher than the cost of supply in order to subsidise households in other areas of Fiji.[75] The "lifeline" tariff provided to low-volume consumers is another non-commercial obligation that has been borne by the FEA in recent years.

[75] All of Fiji with the exception of the Suva-Nausori corridor fitted into this category in 2002 (Mar 2002).

- Renewable energy targets – The FEA set a target of generating 90 per cent of its power from renewable technologies by 2011, a target that has since been postponed to 2015 (FEA 2007a; FEA 2008a; FEA 2008b; FEA 2011). This target is consistent with the *National Energy Policy* approved in 2006 (Department of Energy 2006a). In addition, annual non-commercial performance objectives given to the FEA normally include a minimum percentage of renewable power generation (FEA 2009a; FEA 2010).

These objectives are illustrated in figure 4.2.2c.

Figure 4.2.2c FEA Objectives



There is conflict between these three sets of objectives. In the case of the first and second set, the *Public Enterprise Act (1996)* states that the government must reimburse non-commercial obligations met by public enterprises. This does not occur in the case of the

FEA. Instead, a rather unclear accounting system has been developed (based on a cabinet decision made in 2002), in which the government considers the non-commercial obligations met by the FEA as its return on capital. In 2010, the FEA estimated that non-commercial obligations amounted to approximately FJ$30 million (FEA 2010). The issue of non-commercial obligations is set to become more problematic when the FEA is partially privatised, as they have the potential to conflict with commercial objectives and will be opposed by private sector shareholders.

The effect of giving the FEA multiple and conflicting objectives is that it is difficult for FEA management to set a clear direction for the organisation. Assessment of management performance is also made more difficult. FEA actions to date suggest commercial objectives are pursued to the extent possible within a framework of meeting non-commercial obligations. Renewable energy technologies are also accommodated under these objectives, due to their lower generation costs relative to oil-based electricity generation. However, FEA investment in renewable technologies has focused on hydro-power technology. The reasons for this are explored in the next section. Energy efficiency measures are also not a priority for the FEA, which does not have an incentive to reduce power consumption. (as discussed below). The commercial objectives of the FEA are largely determined by electricity tariff determination. This is discussed in the next section.

4.2.3 Patterns of Interaction and Incentives

Rate Regulation: Theory

The commercial objectives and investments of electricity generators are framed by rate regulation. The literature identifies two principal forms of rate regulation. The first is rate of return regulation, which provides the utility with a "fair" rate of return on its investments. This commonly involves setting the utility's rate of return so that it is slightly higher than the cost of capital. Tariffs therefore reflect power generation costs under this system. The benefit of rate of return regulation is that efficiency gains made by the utility are transferred to consumers in the form of cheaper electricity prices. The problem with rate of return regulation is that the utility is provided with little incentive to improve efficiency, as the regulator will lower electricity tariffs in response to any decrease in electricity generation costs (Pedell 2006).

The second form of regulation is price cap regulation. Price cap regulation is based on the idea that the utility should be entitled to retain efficiency gains in the form of higher profits. Electricity tariffs under a price cap system are set at a given level for a number of years, allowing the utility to profit if it reduces costs. The benefit of price cap regulation is that the utility has an incentive to lower costs and improve efficiency. The problem with price cap regulation is that lower costs are not transferred to consumers in the form of lower prices.[76]

Rate regulation in the real world does not conform perfectly to either model. Instead, a continuum exists with rate of return and price cap regulation at either end of the spectrum. A number of factors determine the location of a country's regulatory system on the spectrum, with the length of the review period for tariffs being particularly important (Pedell 2006).[77] The greater the length of the regulatory review period, the closer rate regulation conforms to the price cap model. The utility under such a system has an incentive to lower costs in order to increase its profits prior to the next review. It is also more exposed to financial risk, as tariffs will not reflect changes in costs.

The shorter the review period, the more regulation approximates the rate of return model. The utility under this system has little incentive to improve efficiency, as lower costs are passed on to the consumer as lower prices. It is also less exposed to financial risk, as tariffs will reflect costs. This can favour investment in technologies with high upfront costs, as the risks associated with such investments are borne by the consumer (passed on through prices established by the regulator) (Pedell 2006).

[76] Tariffs determined under price cap regulation are commonly linked to:

- a retail price index that allows tariffs to increase in line with the prices of other goods and services; and/or
- efficiency targets/dividends, which involve tightening of the price cap (or reducing tariffs) over time, in order to transfer efficiency gains to consumers.

Tariffs under price cap regulation are reviewed every two to five years in most cases (Pedell 2006).

[77] Also important are targets and coverage of regulation, the degree of regulatory discretion, and how this discretion is used by the regulator (Pedell 2006).

Rate Regulation in Fiji

Tariff setting in Fiji involves a number of trade-offs and conflicting objectives. Government considers lower tariffs beneficial due to their political implications, and impact on economic growth, given the role of electricity as a business input. On the other hand, higher tariffs are also advantageous, as they facilitate expansion of the FEA grid, investment in renewable energy technologies, and improved fiscal revenue from the FEA. These features promote economic growth and reduce tariffs in the long term.

Tariff setting in Fiji is also highly politicised. Increasing electricity tariffs is unpopular, and stakeholder lobbying has some influence on tariff determination. Tariff setting by an independent regulator allows the government to avoid the negative political implications of higher tariffs to some extent, as blame is directed at the regulator. De-politicisation of tariff setting is the primary reason for establishing independent regulation throughout the world (Choynowski 2004; Gratwick and Eberhard 2008; Pedell 2006).

Regulation of the FEA is more similar to rate of return than price cap regulation. The Commerce Commission sets electricity tariffs so that they are “reasonable” and “reflect a competitive market price” (Commerce Commission 2010c: 1-2). At the same time, the Commerce Commission recognises that the FEA is “to take a lead role in making investments in renewable energy projects”, and that this means it should be “able to make reasonable return to fund its capital investment projects” (Commerce Commission 2010b; Commerce Commission 2010d: 1-2). This potentially means setting tariffs that provide the FEA with an above average rate of return on investment. The powers of the Commerce Commission are also constrained by the threat of possible government intervention, as has occurred in the past. It is therefore likely to consider what is politically acceptable to the government when setting tariffs.

The length of the regulatory review period used by the Commerce Commission influences FEA incentives with regard to commercial objectives and risk aversion. In recent years, the review period for tariffs in Fiji has changed. The Commerce Commission has increased the frequency of its tariff reviews, establishing a system that approximates rate of return regulation. This has facilitated investment in technologies with a high upfront cost, such as hydro-power, by transferring risks to the consumer. It has not however completely erased FEA incentives to reduce costs or avoid risk. Tariff movements have been less pronounced than cost movements, and have been arbitrary as a result of government interference.[78]

The present day system of tariff determination has provided FEA management with some incentive to produce power at least cost, with the goal of generating commercial returns. It has also meant that FEA management is somewhat averse to oil price risk, although not to the extent it would be under price cap regulation. These incentives, together with non-commercial objectives set by government, have resulted in the ambitious renewable technology investment program outlined in chapter three.

Tariff regulation in Fiji provides the FEA with no incentive to promote energy efficiency among consumers. The FEA currently has no financial incentive to reduce power consumption. It has implemented several energy audits for large customers, consistent with the *National Energy Policy's (2006)* promotion of energy efficiency. However, such projects are not a priority, as demonstrated by the piecemeal nature of its reported energy efficiency activities (see various FEA annual reports). The lack of incentives to undertake demand side management by the FEA is best demonstrated in the history of the energy efficiency unit. The unit was established some years ago on the recommendation of the FEA Board (which represents a broader government viewpoint). However FEA management dedicated only two staff to the new unit, and provided it with no budget support. The FEA therefore successfully paid "lip service" to the promotion of energy efficiency measures, with little significant change in its operations.

At the same time, rate of return tariff regulation has also allowed the FEA to invest in renewable technologies with high upfront costs in the knowledge that it will receive a return on such investments. This may partly explain the FEA's pursuit of hydro-power, although other factors are also likely to be important. These include experience with the

[78] An example is the Commerce Commission's introduction of a fuel surcharge from 2006 to 2009 in response to higher fuel prices (Commerce Commission 2006). This surcharge only partially shielded the FEA from higher fuel prices (FEA 2006; FEA 2007a; FEA 2008a; FEA 2009a). Furthermore, ministerial cancellation of a fuel surcharge increase in 2008 showed that such protection is not guaranteed.

technology, especially the positive experiences associated with the Monasavu hydro-power scheme. The negative experience with the Butoni wind farm is likely to make FEA management wary of investments in technologies with which they have no experience, and could explain the focus on IPP investment for biomass, bagasse and geothermal development. The fact that biomass and bagasse are linked to existing industries also probably plays a role in discouraging direct investment by the FEA.

Recent announcements by the Commerce Commission may suggest a move towards a system resembling price cap regulation. The latest “Tariff Alignment” was “a much broader review of FEA tariff structure”, and was presented as one that would remain in place for a longer period (Commerce Commission 2010b; Commerce Commission 2010c; Rina 2010a). If this is the case, it may provide FEA management with added incentive to reduce costs and reap the benefits prior to the next review of tariffs. A clear statement from the Commerce Commission setting the duration of the present tariff determination would increase incentives for FEA management to lower costs in the future. It would also encourage investment in low-cost, low-risk renewable technologies.

Independent Power Producers: Incentives

Independent Power Producers (IPPs) also invest in generation capacity in the electricity sector. IPPs are motivated by profit, which is determined by the feed-in tariff paid by the FEA for electricity sold to the grid. Feed-in tariffs are established in Power Purchase Agreements (PPAs) signed between the FEA and IPPs, and if set in a competitive market, should reflect the marginal cost to the FEA of producing electricity, minus a transmission and distribution fee paid by the IPP to the FEA. Theoretically, IPPs should be able to make a profit through investment in renewable energy technologies, as these have marginal costs that are far below the marginal cost of generation for the FEA (which is the cost of oil-based generation).

PPAs are negotiated individually between the FEA and each IPP. In the past, the FEA used its monopsony position to ensure that PPAs established very low tariffs.[79] In the case of the

[79] Monopsony refers to a situation where a buyer is the single purchaser of a product from several sellers.

Fiji Sugar Corporation (FSC), excess power produced by its mills was sold to the electricity grid in 2009 for just 8.8 FJc/kWh, far below the average tariff rate and the cost of power generation (Interview with FSC, August 2009). This provided the FSC with no incentive to invest in electricity generation capacity additional to its own requirements, and explains the failure of FSC to replace its ageing generators (Interview with FSC, August 2009; Prasad 2003). Low feed-in tariffs also prevented significant investment in the electricity sector by IPPs more broadly.

It is difficult to determine what the FEA's incentive was for insisting on such low feed-in tariffs, as the FEA benefits financially from IPP investment in capacity that replaces oil-based generation. This sort of counter-intuitive behaviour is not unique in developing countries. Gratwick and Eberhard (2008) note that electricity utilities are in many places hostile to the entrance of IPPs, even where this relieves financial pressure. The explanation probably relates to a perceived loss of monopoly control over the electricity grid.

Government promotion of electricity generation by IPPs, reflected in the *National Energy Policy (2006)* and in the performance objectives of the FEA, has in recent years placed pressure on the FEA to pursue PPAs. Agreements signed with new IPPs have therefore offered higher feed-in tariffs. In the case of Tropik Wood, the biomass plant constructed in 2008 received 13 FJc/kWh (Interview with Tropik Wood, August 2009; SMEC 2009). Although this is an increase on previous PPAs, it is still well below the cost of oil-based generation (which chapter three demonstrated is in excess of 37 FJc/kWh). The low feed-in tariff can be partly attributed to low average tariffs received by the FEA at the time (which were set at 22.2 FJc/kWh) (Chaudhary 2010b).

In 2010, a minimum feed-in tariff of 27 FJc/kWh was established by the Commerce Commission as part of its "Tariff Alignment", which also increased the average tariff rate to 39 FJc/kWh. The Commerce Commission determination reflected the more assertive nature of the Commerce Commission, the low feed-in tariffs previously paid by the FEA, and the FEA's monopsony position in relation to IPPs.[80]

[80] The *Commerce Act (1998)* had always provided the Commerce Commission with powers to review PPAs and to arbitrate in case of disputes between the FEA and IPPs. These reviews had not occurred in practice. The Commerce Commission noted in its 2010 determination that feed-in tariffs should vary based on

Minimum feed-in tariffs established by the Commerce Commission are likely to encourage investment in generation by IPPs, as illustrated by recent plans for private sector investment in biomass plants. Feed-in tariffs established in PPAs also provide IPPs with incentives to generate power at least cost. Agreements are offered for a 15 year period at a fixed rate and effectively operate as a form of "price cap" regulation. This enables IPPs to retain savings achieved through lowering generation costs

There are nevertheless a number of barriers to investment by IPPs. The most significant is political uncertainty and regulatory risk. Investors are likely to be concerned about strong political opposition to the Commerce Commission and its tariff determinations (examples of such opposition include: Chaudhry 2010; Fiji Daily Post 2008; Intelligentsiya 2009a; Intelligentsiya 2009b; Prasad 2009; Solivakasama 2008). Related barriers to investment by IPPs include access to financing, which is made more difficult due to political uncertainty in Fiji, and access rights to land and fuel resources (Pacific Renewable Energy Limited 2011). These barriers are discussed in chapter seven.

4.2.4 Outcomes

This section has discussed the impact of institutional arrangements on investment in Fiji's power sector. The FEA is notionally independent from government and is required to pursue commercial objectives under the *Public Enterprise Act (1996)*. It is also given non-commercial objectives by government through performance objectives, approval of annual corporate plans, and appointment of the FEA board.

What does this mean for investment in renewable technologies? The FEA's planned investment in renewable energy technologies is consistent with both commercial and non-commercial objectives. The FEA has focused almost exclusively on hydro-power due to previous experience with the technology, and guaranteed returns on its investments under

production costs and the location of power plants, and that the minimum feed-in tariff rate should therefore be considered a floor rather than a standard rate (Commerce Commission 2010c; Commerce Commission 2010d).

rate of return regulation. Reform of the tariff determination process in the last six years has facilitated this investment, with higher tariff rates providing the FEA with resources to invest in renewable technologies. New feed-in tariff rates established by the Commerce Commission in 2010 are also facilitating investment by IPPs.

In the future, a more stable tariff rate may provide the FEA with greater incentive to reduce costs, given the potential for generators to retain profits under price cap regulation. This should also encourage investment in renewable technologies, especially low-cost, low-risk technologies such as geothermal, biomass and bagasse. Government removal of the excise duty exemption on FEA fuel in 2011 will likewise facilitate investment in renewable technologies by making oil-based generation more costly. Its reimbursement of lifeline tariff costs incurred by the FEA is another step toward making commercial objectives paramount for FEA management.

A number of barriers to investment in renewable technologies remain, and are likely to mean the FEA does not achieve its goal of generating 90 per cent of power from renewable technologies in 2015. In the sugar industry, financial difficulties in the FSC and declining sugar production are adversely affecting electricity generation from bagasse. This is outside of the control of the FEA or Commerce Commission, but is an issue the government is attempting to address. A more general barrier to renewable power investment is regulatory uncertainty. This is the result of political instability in Fiji. Regulatory uncertainty has slowed investment in the power sector, by making potential IPPs cautious about investment in Fiji, and by making access to finance more difficult. The current regulatory system also provides the FEA with no incentive to promote improved energy efficiency among its customers. These barriers are explored in chapter seven.

4.3 Electricity Sector Regulation: The Policy Level

Recent investment in renewable technologies in Fiji is in large part the result of regulatory reform in the electricity sector, especially tariff determination. This section examines electricity sector regulation at the (national) policy level. It explores the reasons for existing institutional arrangements by looking at physical conditions in Fiji's electricity grid, international trends in power sector reform, and the history of public enterprise reform in Fiji. In doing so, it provides insights into the institutional arrangements that are feasible in Fiji's power sector, and discusses scope for further reform. The analysis provides the context for a discussion of policy implications in chapter seven.

4.3.1 Action Arena: Actors and the Action Situation

The Government of Fiji establishes regulatory arrangements in the electricity sector. Cabinet plays the key role in determining regulatory arrangements in the electricity sector through presenting legislation to parliament (or issuing decrees in the present political climate), and exercising executive powers. The Fiji Public Service supports this decision making through its advice to cabinet and implementation of cabinet decisions. Public servants interviewed as part of this research described a hierarchy within the Fiji Public Service, with the central ministries of national planning, finance, and public enterprises being particularly powerful (Interview with present and former Department of Energy management, November and December 2009).

International donors are also involved in establishing regulatory arrangements in the power sector. Donor organisations have had considerable impact on regulatory arrangements in Fiji's electricity sector, as well as on the broader public enterprise reform agenda (Maunsell Limited 2005; Prasad and Tisdell 2006; Sarker and Pathak 2003).[81] FEA management also

[81] International ideas are transferred to Fiji in various ways. Donor assistance to Fiji has been the primary mechanism for the transfer of international ideas and best practice regulatory arrangements. This occurred in the power sector with the unbundling of the FEA in 1998. The commissioning of reports by the public service is another means through which ideas are transferred. In the electricity sector, the influence of these reports has been the result of a lack of power sector regulation expertise in the Fiji Public Service (Maunsell Limited

makes submissions to government and has some impact on regulation through its role in electricity sector planning. A number of domestic organisations lobby government with regards to regulation of the electricity sector, especially tariff determination. Political parties and trade unions have been the most important in Fiji, as described below. Other non-government lobby groups are active and were discussed in section 4.2.3.

4.3.2 Influences on the Action Arena (or Context): Physical Conditions, Attributes of Community and Rules-in-Use

Rules-in-use

Reform in the power sector in Fiji occurs under the same rules used for establishing other laws. At the time of writing, the interim military government rules using decrees issued by the interim cabinet. This system involves few checks and balances, with cabinet members not elected and no parliament in place to block, amend or debate legislation. Formal rules-in-use tell only part of the story. Electricity sector reform is a specialised body of knowledge and cabinet members, whether elected or not, depend heavily on advice from experts and the Fiji Public Service. This explains similarities in the power sector reform objectives of present and previous governments.

Physical Conditions

Physical conditions both establish the need for regulation and limit the number of regulatory arrangements that are feasible in Fiji's power sector. The electricity sector has traditionally been considered a natural monopoly across the world due to large sunk capital costs that restrict entry into the sector, and economic inefficiencies associated with duplication of transmission and distribution infrastructure. As a result, regulation of the electricity sector has been used to balance the interests of consumers and the monopolistic

2005). Finally, international ideas are transferred to Fiji through the education of Fijian public servants overseas.

utility (Pedell 2006). Regulation of the power sector has also been implemented due to the public good nature of electricity. Electricity does not meet the strict definition of a public good, as consumption is excludable.[82] It can however be considered a public good in a broader sense, as it is a necessary input to other economic and social activity. This is a quality not captured by its price (UNDP 2003: 111).

Since the 1980s, competition in electricity generation and distribution/retailing has been established in many countries through regulatory reform, with the goal of improving the performance of utilities. This has challenged the traditional understanding of the power sector being a natural monopoly, as discussed below (Choynowski 2004).[83] The small scale of power generation in Fiji limits this potential for competition. The Monasavu hydro-power scheme in Fiji produces over half of the country's electricity and its owner would inevitably have significant market power in a competitive market for electricity generation.[84]

The small scale of power generation in Fiji also creates a trade-off between potential benefits from competition and benefits from economies of scale. There are a number of studies that point to the significant economies of scale to be had in the electricity sector. In terms of generation, it is generally accepted that economies of scale increase rapidly to about 100 MW capacity, and continue to increase at a slower rate to 500-800 MW (Lovins, et al. 2002; Stoft 2002). The electricity grid in Fiji has a peak demand of only 138 MW, with installed power of approximately 200 MW (FEA 2009a). This generation capacity is divided among a number of grids, with the largest (the VLIS) being effectively split into two smaller grids by transmission bottlenecks (Maunsell Limited 2005). Economies of scale are also associated with the operation of a number of smaller generation plants. Large utilities can hire specialists and maintain spare parts and repair crews (Choynowski 2004). In contrast, the existence of multiple small utilities can result in the duplication of resources, such as administrative staff, and can cause problems in recruitment of employees

[82] This means that consumption can be prevented where a person does not pay for power.
[83] It does not mean that regulation is no longer needed. Indeed, competition has only been made possible by regulatory arrangements, such as the establishment of wholesale markets for power (Choynowski 2004).
[84] Dahl (2004) notes that a similar problem was faced in New Zealand, where excess capacity and the dominance of low-cost hydro-power resulted in significant barriers to entry in the newly formed electricity market following reform.

where national expertise is scarce. This is particularly relevant in Fiji (Maunsell Limited 2005).

Attributes of Community

The attributes of actors involved in establishing power sector regulation were discussed in section 4.2.2. The discussion below further contextualises electricity sector regulation by considering international power sector reform and the history of public enterprise reform in Fiji. These two subjects are central to an understanding of why electricity regulation in Fiji exists in its present form, and provide insights into the feasibility of future reform.

International Power Sector Reform

International thinking and practice on power sector reform has had a significant influence on power sector regulation in Fiji. Beginning in the 1980s, there was a push throughout the world to introduce competition into what had traditionally been state-dominated power sectors. In many cases, privatisation of state-owned electricity utilities was also advocated. It was argued that the introduction of competition and private sector participation could increase efficiency and lower generation costs. In developing countries, it was also argued that reform could improve power sector performance through better maintenance and collection of adequate tariffs, and widen access to electricity through private sector financing of grid expansion and investment in generation capacity (Choynowski 2004; Gratwick and Eberhard 2008; Rosenzweig, et al. 2004). This thinking was transferred to Fiji through support and advice provided by donors and consultants.

Power sector reform can be understood with reference to four models of regulation identified in the literature (Choynowski 2004). These are illustrated in table 4.3.2a. State-owned vertically integrated monopolies are the most common form of power utility found in developing countries. The second most common structure is the monopsony model, where limited competition is introduced in electricity generation through the sale of power to the dominant utility by Independent Power Producers (IPPs). The third and fourth models are more complex, involve more competition, and require the "unbundling" of the dominant power utility.[85]

Table 4.3.2a. Regulatory Structures in the Power Sector

	Operational Model	Regulatory Structure
Less competition ↑	Vertically Integrated Monopoly	Full regulation of generation, transmission, distribution, and retail components.
	Monopsony	Full regulation of transmission, distribution, and retail components. Competition to enter generation level.
	Wholesale Competition	Full regulation of transmission, distribution, and retail components. Generation regulated by the market.
More competition ↓	Full Customer Choice	Full regulation of transmission and distribution components. Generation and retail regulated by the market.

Source: Adapted from Choynowski (2004)

The four models of power sector are commonly represented as a continuum involving different levels of competition. Gratwick and Eberhard (2008) argue that this continuum was used in the past to demonstrate progress in power sector reform, with countries expected over time to move from a vertically integrated monopoly to a full customer choice model.

The suite of reforms was not implemented in its entirety in the majority of developing countries. In an extensive review of electricity sector reform in 150 countries, Besant-Jones (2006) found that only 19 countries had introduced extensive competition in both distribution and generation, and that this had occurred primarily in Europe and Latin America. Vertically integrated monopolies remained in place in 79 countries; while in 52 countries, IPPs sold electricity to a single buyer. No country with less than 1,000 MW of

[85] The "wholesale competition model" involves full competition at the generation level, with distribution companies bidding for electricity from generation companies in a wholesale market. The "full customer choice" model involves competition at every level of the power sector with the exception of the transmission and distribution network.

installed capacity had established a wholesale market, a finding that is very relevant to Fiji. Gratwick and Eberhard conclude that the "standard model" of power sector reform in developing countries is inaccurate, and that instead:

> What we find in the power sector of most developing countries is a confused and contested policy and institutional space that arises from the fact that the incumbent state-owned utility remains intact and dominant, but where IPPs are also invited into the market, often with less than enthusiastic support from the incumbent (2008: 3958).

The failure of most developing countries to implement the full suite of reforms described above is in large part the result of the different conditions and challenges faced in those countries. Reform in developing countries was commonly the result of crises in the electricity sector where supply had not kept pace with rising demand for power (Gratwick and Eberhard 2008). It was hoped that reform would lead to investment in electricity sector infrastructure by the private sector. Reform was not primarily motivated by efficiency arguments or ideological reasons, as was the case in most early reformers and developed countries (Newbery 2001). Where investments did not materialise, reforms were commonly abandoned. Political obstacles also prevented reform. Reform generally required an increase in electricity tariffs, which in many cases were below the cost of generation. There was strong opposition to this. Similarly, privatisation of power utilities was commonly opposed by trade unions and others with interests in the *status quo* (Besant-Jones 2006; Choynowski 2004).

Support for electricity sector reform has wavered in the last decade as a result of mixed experiences (Besant-Jones 2006).[86] In developing countries, there is increasing recognition of the difficulties and significant risks entailed in implementing power sector reform, especially in relation to establishing effective markets where supply and demand are highly inelastic (or less responsive to price signals) (Besant-Jones 2006; Borenstein 2002;

[86] Possibly the most famous example of problematic reform is the power crisis that affected California in 2001 (Borenstein 2002; Choynowski 2004). In other countries, reform has also not always been as beneficial as was once posited. In both the United Kingdom and Chile, two countries commonly cited as examples of successful power sector reform, prices for consumers have not fallen despite lower generation costs resulting from efficiency gains (Choynowski 2004; Gratwick and Eberhard 2008). This is largely due to monopoly power among private sector utilities and the existence of price cap regulation. A full account of the successes and failures of electricity sector reform is provided in Besant-Jones (2006) and Choynowski (2004).

Rosenzweig, et al. 2004). Where reforms have been successful, they have involved careful sequencing and have been supported by good governance structures. As a result, most examples of successful reform have occurred in developed countries (Besant-Jones 2006; Choynowski 2004; Gratwick and Eberhard 2008; Kessler and Alexander 2005).

Some analysts consequently caution against liberalisation where state provision of services is inadequate. Their argument is that liberalisation places "more rather than less demand on effective and capable public authorities (because) intervention through incentives requires more skill than intervention through investment" (Thompson 2002 cited in Kessler and Alexander 2005: 32). Governments therefore need to have both the political will and capacity to pursue successful reform. Similar points are made in the *Human Development Report 2003* (UNDP 2003). Besant-Jones summarises these arguments in relation to power sector reform, stating that "The case of unbundling gets weaker the smaller the system, the more undeveloped the institutional capacity, and/or the weaker the general country conditions" (Besant-Jones 2006: 61).

The World Bank and ADB, both strong advocates of power sector liberalisation in the past, have arrived at similar conclusions. Both organisations now argue for reform on a case-by-case basis (this is discussed in Appendix A4.1) (ADB 1995a; ADB 2009a; Gratwick and Eberhard 2008). In relation to Pacific island countries, the ADB and World Bank continue to argue for private sector participation in Pacific island countries, but in the form of contracting functions to the private sector and introducing IPPs (ADB 2008; ADB 2009a; ADB 2010; World Bank 2006a). [87] This experience is relevant to Fiji given past experiments with power sector reform and continued advocacy for power sector liberalisation by some analysts. The Fijian experience is discussed in section 4.3.3.

[87] The electricity utility in Vanuatu, UNELCO, is commonly cited as an example of a private sector utility operating in a small island developing state (ADB 2010; World Bank 2006a). Inadequate regulation, very high prices (resulting from the purchase of expensive generation equipment) and a lack of access to electricity among a large part of Port Vila's population suggest that this is not an example to follow, despite UNELCO's provision of high quality electricity. This view is not shared by all (see for example Castalia (2004)).

In Fiji, relations between government and public enterprises have framed government regulation of the FEA. The 1994-99 reform agenda of the SVT (*Soqosoqo ni Vakavulewa ni Taukei*) government was based on private sector-led economic growth with a focus on public sector reform. The *Public Enterprise Act (1996)* was introduced in order to improve efficiency in the public sector following increasing fiscal difficulties related to a poorly performing economy, expanding civil service, and the failure of the National Bank of Fiji (Appana 2003; Department of Public Enterprises 1998; Reddy, et al. 2004). In many cases, reform of public enterprises was considered a first step towards privatisation (Appana 2003). These ideas were strongly promoted at the time by aid donors.

Between 1997 and 1999, 13 state-owned organisations or units within organisations were named "reorganisation enterprises" (McMaster 2001).[88] The reorganisation of these enterprises achieved mixed results, and in some cases suffered considerable difficulties. The failed reform of the Civil Aviation Authority of Fiji and the Government Shipyard and Public Slipways is outlined in Appendix A4.2. In the case of Telecom Fiji, a monopolistic public enterprise was privatised only to form a private sector monopoly (Reddy, et al. 2004).[89] Reddy et al. (2004) report that in many cases, public enterprises were corporatised for the sake of corporatisation. Government in these instances established no performance indicators and the directors remained the same (albeit on higher private sector wages).

The election of the Fiji Labour Party (FLP) to government in May 1999 stalled and in some cases reversed the public enterprise reform process. The new government was intent on maintaining public control over utilities.[90] The Prime Minister, Mahendra Chaudry, had

[88] These enterprises included Airports Fiji, the Fiji Broadcasting Corporation, the Fiji Hardwood Corporation, the Fiji Water Corporation, Fiji Ports Terminal, the Public Trustee Corporation, Shipbuilding Fiji, and the three power sector corporations established with the unbundling of the FEA. In addition, government shareholdings were completely sold in the case of Tropical Food Processors, and were reduced to 51 per cent in the case of three public enterprises: Air Pacific, Amalgated Telecom Holdings, and the National Bank of Fiji.

[89] Amalgated Telecom Holdings is the parent company of Telecom Fiji.

[90] For example, the new Prime Minister stated in his opening address to parliament:
"Government is serious in reviewing the public enterprise restructuring and privatisation program with a view to halting its redundancy impact. In addition, strategic utilities such as water, electricity, telecommunications and civil aviation entities must remain under State control as viable units. Government will therefore reverse all moves to privatise such enterprises…" (as cited in McMaster 2001).

strong links with trade unions, having previously worked as the General Secretary of the Fiji Public Service Association. The FLP had opposed both privatisation and the dismissal of employees under the public enterprise reforms, and had campaigned on an anti-reform platform in the run-up to the election. Its unexpected victory in the election was partly the result of this opposition to reform.[91]

The new government reversed various reforms. It returned the newly formed independent water utility, Fiji Water, to the Ministry of Works, and abolished the Commerce Commission that had been established to independently regulate key monopolies. Problematic reforms in the Civil Aviation Authority of Fiji and the Government Shipyard and Public Slipways were also reversed.

Reform recommenced with the overthrow of the FLP government in the 2000 military coup, and the victory of Laisenia Qarase's *Soqosoqo Duavata Lewanivanua (SDL)* government in subsequent elections. Reforms under the SDL government were however moderate and consistent with its pro-indigenous agenda (Appana 2003; Prasad and Tisdell 2006; Sarker and Pathak 2003). The *Social Justice Act (2001)* ensured that there were to be no forced redundancies as a result of corporatisation or privatisation and that reform would favour indigenous Fijians.[92] This limited efficiency gains and the true commercial orientation of public enterprises.

In retrospect, the failure of the reform process in Fiji demonstrated a lack of public support or political consensus (as discussed in Appendix A4.3) (Dubsky and Pathak 2001; McMaster 2001; Narayan 2005; Narayan 2010; Prasad and Tisdell 2006; Reddy, et al.

Reform did not stop entirely. In some public enterprises, new management with private sector experience were appointed to management boards (Appana 2003). The results however were never given the opportunity to materialise. In May 2000, the Fiji Labour Party government was removed in a civilian coup orchestrated by nationalistic indigenous groups opposed to "Indian" rule.

[91] The electoral victory of the Fiji Labour Party has since been attributed completely to its opposition to the reform process by some analysts (Snell and Prasad 1999). This is an oversimplification, with the election result due to many factors, such as an Alternative Vote system that ensured preferences from moderate indigenous Fijian parties (opposed to more nationalistic discourses) were transferred to the Indo-Fijian dominated Fiji Labour Party (Fraenkel and Grofman 2006). This resulted in a parliamentary majority for the Fiji Labour Party, which gained 52 per cent of parliamentary seats with only 32 per cent of the first-preference vote.

[92] For example, at least 50 per cent of shares floated were to be offered to indigenous Fijians, who could access special government assistance to purchase them (Government of Fiji 2002). Similarly, indigenous Fijians were to acquire 50 per cent of contracts where goods or services were contracted out to the private sector (Sarker and Pathak 2003).

2004; Sarker and Pathak 2003). Reform was used for political purposes by all parties. The Fiji Labour Party used its opposition to reform as a rallying cry during elections, while the SDL used reform as a means of imposing its pro-indigenous agenda. The current interim military government's support for reform can be understood in terms of the fiscal crisis it faces, as outlined in the next section.

The failure of the public enterprise reform process in Fiji also demonstrated a lack of capacity and experience within the government and public service (Hook 2009; McMaster 2001; Reddy, et al. 2004). This was clearly visible in the disastrous attempt to privatise the Government Shipyard and Public Slipways, where the government failed to perform even basic due diligence on the private sector entity purchasing the company. There are a number of similar examples of failures in government at the time, including the bankruptcy of the National Bank of Fiji, and the significant financial losses associated with construction of the *Reef Endeavour* catamaran (Narayan 2010).

These failures are commonly attributed to a lack of expertise and experience in the civil service (Appana 2003; Prasad and Tisdell 2006: 20; Reddy, et al. 2004; Sarker and Pathak 2003). The Fiji Public Service, which had been capable and well organised following independence, deteriorated as a result of the 1987 coup, which led to the appointment of managers on the basis of ethnicity and/or provincial allegiance (Appana 2003; Prasad and Tisdell 2006: 20; Sarker and Pathak 2003). These changes and poorly targeted affirmative action programs were also associated with corruption, as highlighted annually in reports of the Auditor-General (Reddy, et al. 2004). Sarker and Pathak argue that:

> The existence of the patronage distribution system, corrupt practices, ethnicity and social heirarchy-based public employment have hindered the process of implementing formal declarations of governments towards market-oriented reforms (Sarker and Pathak 2003: 71).

This legacy remains firmly in place today. Gani and Duncan (2007) measured government effectiveness in Fiji between 1985 and 2003, and found little improvement, with significant reductions in effectiveness associated with periods of political instability. Since the 2006 coup, capacity has further declined due to the "militarisation of the civil service" and the emigration of senior public servants (Amosa, et al. 2009: 8). A number of public servants interviewed as part of this research project claimed that promotions and dismissals in the Fiji Public Service were based on links (or lack of links) to the interim military government (Interviews with a number of public servants in Fiji, July and November 2009). Similar claims are commonly made and examples given on pro-democracy blogs.[93]

4.3.3 Patterns of Interaction

Reform of the Fiji Electricity Authority

Regulation of the FEA has followed broad patterns of government regulation of public enterprises in Fiji. In 1998, the FEA was listed as a "reorganisation enterprise" under the *Public Enterprise Act (1996)*. It was subsequently separated into three companies responsible for generation, transmission and distribution: PowerGen Fiji, PowerLines Fiji, and MegaPower Fiji. The ADB played an important role in designing this reform process through its technical assistance, which included drafting the *Reorganisation Charter* for the FEA (ADB 1995b; ADB 1998).[94] The changes were short-lived. The following year, the Fiji Labour Party (FLP) was elected to government on an anti-reform agenda. The FLP government brought together the three recently established power companies to again form the FEA, which was removed from the list of "reorganisation enterprises" under the *Public Enterprise Act (1996)*.

Initial "unbundling" of the vertically integrated FEA into generation, transmission and distribution companies was consistent with international trends in power sector reform and experience in developed countries. Later analysis was to consider as ill-conceived the "unbundling" of the FEA (Maunsell Limited 2005). The reforms did not adequately account for the small scale of the electricity sector in Fiji, which prevents effective competition, and reduces existing economies of scale enjoyed by the FEA. The changes also assumed that an appropriate regulatory environment could be quickly established.

[93] See www.coupfourandahalf.com for example.
[94] A reorganisation charter was drafted for every "reorganisation enterprise" under the *Public Enterprise Act (1996)*. The documents detailed the reform program for each public enterprise.

International experience demonstrates that the establishment of independent regulatory mechanisms is a slow and difficult process, particularly where governance is weak and regulatory institutions are new (Choynowski 2004; World Bank 2004). This was the case in Fiji.[95]

Following the political turmoil of 2000, the SDL government recommenced reform of the FEA by appointing a Board of Directors with private sector experience. Significant reform was initiated in 2002 and led to a sharp decline in the number of FEA employees and corresponding improvements in efficiency. Redundancies and the transfer of operational roles to contracted private sector organisations resulted in staff numbers at the FEA falling from a peak of 1050 in 2001 to 569 in 2006 (ADB 2010; Maunsell Limited 2005). System losses were also reduced and tariff collection rates increased. The reforms were a success due to government support for the FEA board despite protest from trade unions and the opposition (World Bank 2006a). Sharma (2009) argues that the re-organisation was relatively conflict-free as it involved consultation with employees but not trade unions (which he argues have a tradition of militancy in Fiji).

The FEA also commenced its current strategy of investment in renewable technologies under the leadership of Josaia Mar (Johnston, et al. 2005; Mar 2002). It implemented a number of small hydro-power schemes through joint ventures with private sector companies. It also prepared the groundwork for both the Butoni wind farm and the Nadarivatu hydro-power projects (which were to be funded by multilateral banks at that stage). Moves to invest in renewable technologies were motivated by commercial considerations. The new management team recognised the importance of expanding renewable-based generation capacity in the face of growing demand for electricity, which could no longer be met by the Monasavu hydro-power scheme (Department of Information 2007; FEA 2002; FEA 2003). Private sector involvement was sought for cost-sharing

[95] At the time the FEA was "unbundled", oversight and tariff regulation remained the responsibility of the Government of Fiji. The Commerce Commission was established in the same year, but remained a weak institution. It did not have jurisdiction over the power sector, with electricity tariffs first designated a "controlled price" by the Minister in 2002 (Maunsell Limited 2005). Appropriate regulation would have been made more difficult still by the lack of power sector expertise in Fiji (FEA 2000). That expertise would have been spread across the three power companies and the Commerce Commission as a result of the unbundling of the FEA (Maunsell Limited 2005).

reasons, and to facilitate the transfer of knowledge (the FEA had not invested in renewable technologies since the early 1980s).

Investment was focused on hydro-power capacity and the wind farm at Butoni. Electricity generation from biomass and bagasse was not pursued. A likely reason for this is that these areas were considered outside the experience and control of the FEA, and an area for investment by industry actors such as the FSC and Tropik Wood. The guarantee of an adequate return on investment under rate of return regulation also favoured renewable technologies with a high upfront cost, such as hydro and wind-power. Geothermal and energy efficiency measures were also not pursued. For geothermal, this was because no geothermal resource had been confirmed in Fiji at the time (it has even today only been confirmed by a pre-feasibility study) (Coutts 2011; Daniel 2010; Nittetsu Mining Consultants Co. Ltd. 2009). For energy efficiency measures, the FEA had no incentives to pursue measures that would result in lower demand for its product.

The SDL government was overthrown in a military coup in 2006. The interim military government subsequently changed the management of a number of public enterprises, including the FEA. The FEA's Chairman of the Board of Directors, Josaia Mar, was removed and replaced by Nizam-ud-Dean, a former chairman of the board in the 1990s. The CEO of the FEA at the time of the coup, Rokoseru Nabalarua, remained in his position until 2007, when he too was replaced by a longstanding manager at FEA, Hasmukh Patel. The FEA's strategy of investment in renewable technologies remained in place throughout this period, motivated by commercial objectives, and from 2006, also by non-commercial objectives outlined in the 2006 *National Energy Policy* and annual performance targets of the FEA. Its focus remained on hydro-power, with "new" technologies left to IPPs following the negative experience with the Butoni wind farm.

The Commerce Commission had already begun to determine electricity tariffs at the time of the military coup. The interim government initially reversed the implementation of a fuel surcharge approved by the Commerce Commission. Later, the interim government moved to strengthen the powers of the Commerce Commission. It provided the Commerce Commission with more staff, an increased budget, and issued the *Commerce Commission Decree (2010)*, giving the Commerce Commission additional powers (as discussed in section 4.2.2). These moves are consistent with international best practice regulation, and have facilitated the "de-politicisation" of tariff determination in Fiji. From a government perspective, moving responsibility for tariff determination to the Commerce Commission meant that tariffs could be increased with less political cost, enabling the FEA to operate in a profitable manner and reducing the need for fiscal support.

Future Power Sector Reform

The interim government announced more significant changes to power sector regulation in late 2010, which are yet to be implemented. The FEA's regulatory role in licensing electricity providers will be moved to another organisation, as has been advocated for some time by the Department of Energy, external consultants and lobby groups (Maunsell Limited 2005; Interviews with Consumer Council of Fiji and Department of Energy, August and November 2009, and July 2010). The removal of this role from the FEA, where it currently resides in a "ring-fenced area", is consistent with best practice regulation and will ensure that the FEA does not block private sector participation in the electricity sector. Again, this move highlights the influence of international thinking on power sector reform in Fiji.[96]

The most significant policy announced by the interim government is the partial privatisation of the FEA. The government plans to sell a 49 per cent stake in the FEA on the South Pacific Stock Exchange in the near future. The interim Minister for Public Enterprises, Aiyaz Sayed-Khaiyum, stated in a press conference that:

> The idea is the government will continue to own the majority of FEA allowing other participants to come into FEA, thereby reducing the dependency on government debt or debt guarantees (Baselala 2010a).

The Minister's statement suggests that an important motivation for the partial privatisation of the FEA is improving the fiscal position of government. This is significant due to the

[96] The interim government also announced that from November 2010, renewal energy businesses will be included in the Reserve Bank of Fiji's Import Substitution and Export Finance Facility. This will facilitate small scale investment in renewable technologies, by enabling renewable energy businesses to access finance at concessional interest rates (backed by the Reserve Bank of Fiji) for loans that are less than FJ$1 million in value (Reserve Bank of Fiji 2010).

sharp increase in government debt since 2007. Between 2006 and 2010, government debt has risen by FJ$515 million, and the government in 2011 will pay FJ$789 million for debt servicing (or half of all government revenue) (Government of Fiji 2010a). The interim government is exploring ways of improving its fiscal position in response (Government of Fiji 2010a). It is hoped the injection of capital in the FEA will enable it to pursue investment in renewable technologies without relying on government financing. The interim government will at the same time retain control over the FEA. It will also remove its fuel subsidy and Value Added Tax exemptions currently in place for the FEA; a move that will further improve the government's fiscal position and should provide the FEA with additional incentive to invest in renewable technologies.

The interim Minister for Public Enterprises made a notable omission in not mentioning efficiency gains in his statement on the partial privatisation of the FEA. Efficiency gains are the primary motivation for privatisation of electricity utilities in most countries. The CEO of the FEA, Hasmukh Patel, did state in support of the privatisation that "perhaps that move might bring about a whole lot more efficiency and bring income to the government" (Rauto 2010). There is however no guarantee of efficiency gains resulting from the partial privatisation, with the government retaining control over the FEA through majority ownership, approval of FEA corporate plans, and appointment of a majority of the Board of Directors. It is difficult to see how governance of the FEA will change under these arrangements. Indeed, there is potential for partial privatisation to result in conflict between shareholders and the government in the future, unless commercial and social goals are clearly delineated and the FEA is pushed to pursue purely commercial objectives. The implications of partial privatisation of the FEA are discussed in more detail in chapter seven.

4.3.4 Outcomes

Reform of the electricity sector in Fiji can be broadly described as a success, despite its slow progress and a number of policy reversals linked to political instability. Pricing functions have been moved from the government to an independent regulator, enabling the establishment of tariffs that reflect the true cost of generating electricity. IPPs are now selling electricity to the FEA at an attractive commercial rate, with a number of IPPs expected to invest in generation capacity in the near future. The FEA, under progressive leadership, has dramatically improved its efficiency and has embarked on an ambitious program of investment in renewable technologies, although this has been restricted mainly to hydro-power.

Electricity sector reform in Fiji has been driven by international best practice, and has involved considerable input from donors and foreign consultants. The process has not been smooth. Reform has been reversed, commonly as a result of political instability, where it has clashed with the interests of certain groups. This occurred with the reversal of moves to "unbundle" the FEA, and more recently with Commerce Commission decisions regarding imposition of a fuel surcharge. Political instability and a lack of local involvement or "ownership" of reform have also slowed the progress of reform. What does this mean for future electricity sector reform in Fiji? Is there scope for additional reform to facilitate investment in low-cost, low-risk renewable technologies?

A number of lessons can be identified from the history of electricity sector reform in Fiji. First, ambitious reforms have failed where implemented without political consensus or support. This highlights the need for broad-based support for reform, and the perils of implementing reform too quickly. Second, limited capacity within government needs to be addressed when designing reform. The success of the Commerce Commission in recent years is the fruit of years of investment in its capacity: effective regulation was not established immediately. Implementation of other government reforms may require similar timeframes. Third, management at the FEA has had a very significant impact on the electricity sector in Fiji. In a few years, progressive management at the FEA effectively reshaped the organisation, initiating its current program of renewable technology investment (FEA 2001; FEA 2002; Mar 2002; Maunsell Limited 2005). The appointment of management that has experience with low-cost, low-risk technologies could help re-prioritise FEA investment towards such technologies and away from hydro-power.

There are limits to power sector reform that is feasible in Fiji. The small size of the electricity grid limits potential benefits from competition due to the loss of economies of scale and the spread of scarce expertise across a number of organisations. The small size of Fiji's power grid also raises questions about the benefits and costs of full privatisation of the FEA. In a grid with limited scope for competition, a strong regulatory system would be needed to prevent a private sector utility from abusing its monopoly position. Past experience of public enterprise reform in Fiji suggests that the establishment of a strong regulatory system would be a challenge, although recent reforms do suggest improvement.[97] This may partly explain the government's reluctance to fully privatise the FEA. Its recent announcement that the FEA would instead be partially privatised is likely to generate other difficulties in the future, as private sector shareholders will oppose government (and majority shareholder) imposition of non-commercial obligations that conflict with the commercial objectives of the FEA.

In terms of reform designed to facilitate investment in low-cost, low-risk renewable technologies, section 4.2 highlighted the benefits of attracting IPP investment to the power sector, establishing effective independent regulation, and ensuring commercial objectives are paramount for FEA management. Reforms to this effect have occurred, and more are underway. The FEA's focus on hydro-power investment is largely the result of its experience with renewable technologies to date, and is likely to change under new management once low-cost, low-risk technologies achieve success in Fiji, and as a result of moves towards price cap regulation. Other measures that could be implemented to encourage investment in low-cost, low-risk renewable technologies are discussed in chapter seven.

[97] Another option envisaged under the Pacific Plan is a regional regulator for several countries. A similar system has worked well in the Caribbean. This seems a very distant possibility in the Pacific islands, given political tensions between states (Pacific Institute of Public Policy 2010).

4.4 Conclusion

This chapter has examined the impact of institutional arrangements on grid-based renewable technology investments in Fiji's electricity sector. The FEA has pursued significant investments in renewable technologies in recent years, in spite of sometimes conflicting objectives under the current regulatory regime. There are several reasons for this. The FEA's commitment to renewable technology investment was first established under progressive management that, with government support, sought to affirm the commercial orientation of the FEA. Investment in renewable technologies was financially motivated at a time when the Monasavu hydro-power scheme could no longer meet growing demand for electricity in Fiji. The use of private sector expertise and capital to assist in these investments was prudent given the lack of expertise in the FEA at the time.

Continued FEA investment in renewable technologies is the result of this legacy. Investments in renewable technologies are warranted commercially, given the high cost and financial risk associated with oil-based power generation. Renewable technology investment is also driven by government influence, manifest through the review of Annual Corporate Plans and Statements of Corporate Intent, annual performance objectives, and the *National Energy Policy*.

Tariff regulation affects the nature of investment in renewable technologies by the FEA. The Commerce Commission in recent years has set tariffs at regular intervals so that they reflect generation costs; a system approximating rate of return regulation. This has guaranteed returns on long-term investments with high upfront costs, skewing incentives towards technologies such as hydro-power at the expense of other renewables such as biomass and bagasse (which have low upfront costs). Also important in this respect have been past experiences, including the positive experience with hydro-power technology, and the problematic experience with "unknown" renewable technologies such as wind-based generation. Tariff regulation has not provided the FEA with an incentive to promote energy efficiency among customers. There has been limited activity by the FEA in this area as a result.

Independent Power Producers (IPPs) provide an alternative means of increasing renewable-based power generation in the FEA grid, and are central to FEA plans for achieving 90 per cent power generation from renewable technologies by 2015. Chapter three described how this goal is unlikely to be met. Investment by IPPs has been hindered historically by very low feed-in tariffs, resulting from the FEA's monopsony position and a lack of regulatory oversight. This barrier to investment has been overcome recently with the Commerce Commission in 2010 establishing a minimum feed-in tariff.

A number of private sector power companies are now considering investments in Fiji as a result. Foreign corporations are nevertheless likely to remain cautious about investing in Fiji, given political instability and arguments against tariff reform by opposition groups. This will also limit access to finance among IPPs. Government moves to strengthen the independent regulator through the *Commerce Commission Decree (2010)* and non-interference in the tariff determination process should encourage further investment in renewables by IPPs in the long run. Continuing uncertainty will remain regarding power generation from bagasse in the sugar industry.

The chapter also looked at power sector regulation at a policy level. Power sector reform in Fiji has been relatively successful, despite slow progress and a number of policy setbacks linked to political instability. It has been motivated by international ideas and best practice regulation, set within the context of public enterprise reform in Fiji. The Fijian experience with power sector reform emphasises the importance of political consensus for reform, and the need to build capacity as part of the reform process. The Fijian experience also highlights the important role of FEA management in the electricity sector. The appointment of new management that has experience with (what are in the Fijian context) low-cost, low-risk renewable technologies would be likely to facilitate direct investment by the FEA in geothermal, biomass and bagasse technologies at the expense of investment in hydro-power capacity. The recent strengthening of the Commerce Commission and potential moves towards price cap regulation should also facilitate such investment.

None of these factors will lead to demand side management. This requires action on the part of government in various areas, to ensure: (i) energy efficiency is given more prominence in the tariff determination process, (ii) building codes better reflect energy efficiency concerns, (iii) wastage in other sectors, such as water supply, is addressed, and (iv) energy labelling and MEPS are implemented. These issues are discussed in chapter seven.

The Government of Fiji recently announced a number of new reforms in the power sector, including the partial privatisation of a 49 per cent stake in the FEA. The objective of this reform is primarily fiscal, with the government set to retain control over the FEA. Institutional arrangements in the power sector are unlikely to change dramatically as a result, although conflict may arise as a result of the government setting non-commercial objectives for the FEA. This could generate pressure for further reform, although complete liberalisation is unlikely given the limited scope for competition and the economies of scale present in a small electricity grid.

Chapter 5
Rural Electrification in Fiji

This chapter explores energy security in rural Fiji, with a particular focus on the provision of electricity in off-grid areas. The first two sections provide an overview of rural power supply and electrification policies. The sections that follow present fieldwork data on: the security of off-grid power supplies, comparative performance of diesel and solar-power technologies (the two primary forms of off-grid electrification in Fiji), and the economic impact of high fuel prices on rural households. Electrification is found to have a positive financial impact on rural households, reducing total expenditure on energy as electricity is substituted for costly lighting fuels. It also has a number of social benefits. At the same time, significant problems with installed electrification systems are identified, with power outages common in both diesel and solar-power systems. Institutional issues are responsible for power outages in both cases.

5.1 Introduction

Energy consumption and power supply are different in rural off-grid areas than in urban and peri-urban parts of Fiji. Threats to the security of supply of electricity are also different. Technical problems are a common reason for power outages, and generally coincide with poor and infrequent maintenance and a lack of money for spare parts. Traditional forms of lighting such as kerosene and benzine are of much poorer quality than electricity, and are also directly affected by high oil prices. The frequent power outages that affect off-grid electricity systems and the poor quality of alternatives highlight the importance of institutional arrangements put in place to provide maintenance to generation technologies. Assessments of power generation technologies and their use in rural areas can also inform rural electrification policies.

The next two chapters explore threats to energy security in rural areas of Fiji, with a particular focus on the security of electricity supply in those areas. Some key questions that the chapters explore are:

- What are the threats to security of off-grid power supply in rural areas of Fiji?
- How have high fuel prices affected rural households and off-grid electricity supplies?[98]
- What are the economic and energy security implications for rural households of electrification using different technologies? Do electrification technologies installed under Fiji's rural electrification programs meet the needs of rural households?
- What impacts do institutional arrangements for the operation and maintenance of electricity generation systems have on electricity supply?

This chapter begins by providing an introduction to rural electrification in Fiji. This includes analysis of the state of electrification in Fiji, and an overview and history of the institutional framework governing rural electrification. Rural electrification under both the *Rural Electrification Policy* and *Renewable Energy Service Company (RESCO) Program* is examined. The chapter then presents empirical data from a survey, focus groups and interviews conducted in July/August and November/December 2009. This fieldwork was focused on diesel and solar-based electrification, given the use of these two technologies for most off-grid electrification in Fiji. Fieldwork also assessed household expenditure on energy in rural areas. Findings show significant financial benefits for households that are electrified, especially where electricity replaces traditional fuels used for lighting. The failure of both the *Rural Electrification Policy* and *RESCO Program* to ensure the sustainability of installed systems is also discussed.

[98] The term "fuel" is used in place of the term "oil" in this chapter. Fuel here refers to petroleum, diesel, pre-mix, kerosene, benzine and other fuels consumed in rural areas of Fiji.

5.2 The State of Rural Electrification in Fiji

The 2007 Fiji Census (2007) provides an overview of electrification in Fiji. It shows that in 2007:

- 74 per cent of all households in Fiji were connected to one of the three FEA electricity grids;
- 11 per cent of households did not have access to electricity;
- 6 per cent had access to a village diesel generator;
- 1 per cent had access to a Public Works Department mini-grid in a government station[99];
- 1 per cent had access to a solar system; and
- 7 per cent had access to another form of generation or provided their own electricity supply.

Table 5.2a presents this data, divided according to the ethnicity of the head of household. The table shows that indigenous Fijian households were less likely in 2007 to have access to electricity than were Indo-Fijian households. Indigenous Fijian households were also more likely to: generate their own electricity; be connected to a village generator; and be connected to a Public Works Department mini-grid near to a Government station. Indo-Fijian households were more likely to be connected to the electricity grid: 88 per cent of Indo-Fijian households were connected compared to 62 per cent of indigenous Fijian households.

[99] There are seven government stations in Fiji, which are established by the central government in order to provide services to rural areas. These centres typically have a hospital, high school, several shops and/or a market, an army barracks, and administrative offices for provincial staff. The government has established mini-grids of several kilometres in length that supply electricity to these centres. Electricity in these centres is supplied from diesel generators that are operated by the Public Works Department. Users pay rates equal to those charged by the FEA, despite substantially higher costs. Government subsidisation of power supplied by these mini-grid is required as a result.

Table 5.2a. Percentage of Households with Different Types of Electricity Supply, Indigenous and Indo-Fijian Households

	Indigenous Fijian Households	Indo-Fijian Households	All Households
Electricity Grid - FEA	62	88	74
Electricity – Village Diesel	12	0	6
Electricity – Solar	1	1	1
Electricity – Public Works Department	1	0	1
Electricity - Other	2	1	2
Electricity – Self Generation	6	4	5
Un-Electrified	17	5	11

Source: Government of Fiji (2007)

The main reason for these differences is that Indo-Fijians are more likely than indigenous Fijians to live in areas where the electricity grid extends. These areas include urban and peri-urban centres, and rural cane growing areas that are near to these centres. Indigenous Fijians on the other hand are more likely to live in isolated rural areas; particularly outside of the main island of Viti Levu, where the presence of the electricity grid is more limited. The reason that almost no Indo-Fijian households are connected to village diesel generators is that households in rural Indo-Fijian settlements are geographically separated from one another by crop areas, making the supply of electricity through a mini-grid economically unviable. This is different from indigenous Fijian households in rural areas, which tend to be located near to one another in tight-knit village structures.

More detailed, albeit dated, data are available from the 2002-03 *Household Income and Expenditure Survey* (HIES).[100] Like the 2007 census, the HIES data show that indigenous Fijians households have lower rates of electrification than do Indo-Fijian households (72 and 88 per cent of households respectively) (Narsey 2006). The HIES also confirms that people in rural areas are less likely to have access to electricity than people in urban areas, as can be seen in table 5.2b. In 2002-03, 92 per cent of households in urban areas had an

[100] A more recent HIES was conducted in 2008-09, however the full results from the survey are yet to be released.

electricity supply, compared to 69 per cent of households in rural areas. When rural households were divided based on ethnicity, 82 per cent of Indo-Fijian households had an electricity supply as opposed to to just 62 per cent of indigenous Fijian households.

Comparing these figures to 2007 census data shows that many Indo-Fijian households have gained access to electricity in the 4-5 year period between 2002-03 and 2007. The same is not true of indigenous Fijian households. It is likely that this is the result of the large number of rural electrification projects that involve extension of the FEA grid into rural cane growing areas, which are primarily Indo-Fijian (this is difficult to confirm, as the HIES does not provide information on type of electricity supply).

Table 5.2b. Electrification Rate: Household Income and Expenditure Survey, 2002-03

	Indigenous Fijians	Indo-Fijians	All
Rural Households	62	82	69
Urban Households	90	93	92
All	72	88	80

The HIES also divides the data on the basis of income deciles, as shown in table 5.2c. Not surprisingly, wealthier households are more likely to have access to electricity in both urban and rural areas, and among both indigenous and Indo-Fijian households.

Table 5.2c Households with access to electricity (per cent)

Household Category	Lowest Income Decile	Highest Income Decile
Urban – Fijian	66	98
Urban – Indo-Fijian	77	99
Rural – Fijian	54	87
Rural – Indo-Fijian	70	93

The same patterns extend to ownership of electrical appliances. This is significant, as ownership of electrical appliances gives an indication of the services that households are likely to demand from a power system. Households in higher income deciles are more likely than those in lower income deciles to own appliances listed in table 5.2d. At the same time, urban areas had far higher rates of appliance ownership than did rural areas, while Indo-Fijian households had higher rates of ownership than did indigenous Fijian households. The biggest difference between the ethnicities was in rural areas. This is partly the result of the type of electricity supplied to households, with rural Indo-Fijian households being more likely to be connected to the electricity grid (which supplies power 24-hours a day, is more reliable than off-grid systems, and has no restriction on household power consumption).

Table 5.2d Percentage of households that own an appliance or have access to electricity

	Urban		Rural	
	Fijian	Indo-Fijian	Fijian	Indo-Fijian
Electrification rate	90	93	62	82
<u>Ownership of:</u>				
Fridge	71	77	22	55
Washing machine	46	48	12	20
Television or video set	74	83	28	66
Computer	7	11	1	2
Telephone	51	68	11	46

Some of these figures are likely to have changed significantly since 2002-03. In particular, mobile phone ownership in Fiji has expanded very quickly in recent years, as has occurred throughout the Pacific islands ('Ofa 2010; Beschorner 2008; Chand and Duncan 2008).[101] The expansion has occurred in both urban and rural areas. Three of the four communities surveyed as part of this research project had mobile phone coverage (although in two communities this was several hundred metres from households). Some families also owned mobile phones. Ownership of computers may also have increased in this period, although its growth in rural areas is still limited. Of the 78 households surveyed in this research project, none owned a computer.

[101] This has been facilitated in many countries by the deregulation of the telecommunications industry and the entry of foreign companies; something that has also occurred in Fiji.

5.3 Institutional Framework for Rural Electrification in Fiji

Government assistance for rural electrification is set out in two complementary sets of rules: the *Rural Electrification Policy* and the *Renewable Energy Service Company (RESCO) Program*. An overview of each is provided below.

5.3.1 The Rural Electrification Policy (1993)

The *Rural Electrification Policy* was established in 1993, and states that the Department of Energy/Rural Electrification Unit will cover 90 per cent of the capital cost of electrification projects, as well as provide free maintenance for three years after installation (Government of Fiji 1993).[102] Households must provide maintenance after this three-year grace period expires. In addition, households must purchase all fuel used to power diesel generators from the time of installation. In effect, this means that the government subsidy is for the capital cost of the technology only, as maintenance issues seldom arise in the first three years. This also differs to the pre-1993 *Rural Electrification Policy*, where the Department of Energy provided maintenance in return for a nominal fee (FJ$110 each year).

In 2008, the interim government increased the subsidy available under the *Rural Electrification Policy* from 90 to 95 per cent of the capital cost of electrification projects (the cap on assistance to households of FJ$3,500 remains in place). The stated purpose of this increase was to alleviate the impact of high fuel and food prices on rural households. The increased subsidy remains in place (despite lower fuel prices in the aftermath of the

[102] The *Rural Electrification Policy (1993)* established a Rural Electrification Unit for implementation of rural electrification projects. It was assumed the unit would operate alongside the Department of Energy. However, the Fiji Public Service Commission did not provide staff for the unit until after 2003. During this ten year period, the Department of Energy instead implemented rural electrification projects. Even now, there is considerable sharing of resources between the Department of Energy and Rural Electrification Unit. Employees in both organisations are housed in the same office space, and report to the Director of the Department of Energy. This dissertation consequently refers to the Department of Energy as an overarching term for both the Department and Rural Electrification Unit when discussing the *Rural Electrification Policy*. The Department of Energy, narrowly defined, is solely responsible for implementation of the *RESCO program*.

Global Financial Crisis). The change effectively halves the amount that rural households must pay upfront for installation of generation technologies, facilitating their access to electricity. The subsidy does not address issues of ongoing payments required to ensure continuous electricity supply, which include the purchase of fuel for diesel generators and the provision of maintenance. These are the two main reasons for the frequent power outages that affect rural off-grid systems.

The *Rural Electrification Policy* allows for electrification using one of a number of technologies. Households choose which technology they want among the viable options, which include:

- FEA grid extensions (for areas near to the electricity grid);
- Extensions of Government station mini-grid diesel systems operated by the Public Work Department (for areas near to a Government station);
- Mini-grid village diesel generators;
- Solar schemes – in practice only solar photovoltaic systems have been installed; although the policy also mentions focal solar schemes; and
- Micro or pico-hydro schemes.

In practice, viable options are limited for most communities in isolated areas.

Extension of the Electricity Grid

Over half of all projects funded under the *Rural Electrification Policy* are grid extensions in rural areas. In most cases, communities seeking grid extensions already have access to an off-grid source of electricity, usually village diesel generators or small household petrol generators (Interviews with Department of Energy staff, July 2009). This is because households near to an existing electricity grid are more likely to live near urban or peri-urban areas, and as a result, to have a source of cash income, either from employment or selling produce in the market. These applications for grid extension can therefore be understood in terms of climbing the "energy ladder" that is commonly referred to in the development literature (Barnes and Floor 1996; Smith 1987; UNDESA 2005; UNDP 2007a). This is also consistent with the goals of the *Rural Electrification Policy*, which aims to provide all households in Fiji with a 24-hour electricity supply (Government of Fiji 1993).

Electricity supplied from the grid is of a superior quality to that supplied by off-grid generation technologies. It is more reliable, is available 24 hours per day, and is much cheaper. The low price of power supplied through the grid is the result of a uniform national electricity tariff rate, through which households in urban areas subsidise households in rural areas. The FEA effectively makes a profit from urban households and a loss from rural households that it supplies. This was discussed in chapter four. Cross-subsidisation through a national tariff rate is common practice throughout the world, and benefits many poor rural households that are connected to the grid. The practice also slows rural electrification, as the FEA has no commercial incentive to expand the grid (it does so due to its non-commercial obligations, as discussed in chapter four). In Fiji, this is most significant in islands where no electricity grid exists, as no power utility will establish a grid unless substantially higher tariffs are charged to consumers (given higher generation costs in small isolated systems).

There are also many parts of Fiji where, tariffs aside, extension of the electricity grid is not economically viable, or where the economic cost of establishing the grid outweighs the economic benefits. This is the result of Fiji's geography and its population distribution, which were discussed in chapter one. Electricity demand among households in rural areas is low. Off-grid electricity generation in such cases is commonly more cost effective than grid extension.

The number of projects involving different technologies that have been implemented between 1993 and 2008 are shown in table 5.3.1a, as are the approximate percentages of total installations those numbers represent.[103] One complete, accurate list of electrification projects was not available. The tables below were instead compiled from government reports and Department of Energy records, and were verified through interviews and discussions with Department of Energy staff. The figures show that extensions of the FEA

[103] The number of installations is more relevant than installed capacity. Solar systems supply considerably less power to households than diesel systems or grid extensions, but can provide similar services if energy efficient appliances are used. Analysis should therefore focus on services provided to households.

grid comprise most rural electrification projects. This is especially the case from 2004, as can be seen in table 5.3.1b. In earlier periods, there was a more even division between diesel and FEA schemes (the large number of FEA extension projects implemented in 2008 skews a more even division between diesel and FEA schemes from 1990 to 2007).[104] Other technologies have been less popular; a majority of solar schemes shown in the tables were in fact implemented under the *RESCO Program* (as detailed below).

Table 5.3.1a. Rural Electrification Projects by Technology, 1993-2008 (number of schemes)

FEA Grid Extension	Diesel Schemes	Solar Schemes	Hydro Schemes	Govt Station Extensions
875 (62%)	487 (34%)	47 (3%)	6 (0.4%)	5 (0.4%)

Source: Department of Energy (2000), Government of Fiji Budget Estimates (2006; Government of Fiji 2007a; Government of Fiji 2008), Matakiviti and Pham (2003), Interviews with Department of Energy Staff (2009 and 2010), Department of Energy Database

[104] There are two conflicting records about FEA installations in 2007 and 2008. The numbers adopted here are taken from budget papers. The Department of Energy database was not used for these years as it was said by Department of Energy staff to be incomplete.

Table 5.3.1b. Rural Electrification Projects by Technology, 1990-2008

Year	FEA Grid Extension	Diesel Schemes	Solar Schemes	Hydro Schemes	Govt Station Extension	Total number of Schemes
1990	0	9	0	0	0	9
1991	0	15	0	0	0	15
1992	0	26	0	0	0	26
1993	0	0	0	0	0	0
1994	5	9	4	1	0	19
1995	10	20	4	1	0	35
1996	17	17	3	0	0	37
1997	16	12	1	0	2	31
1998	38	39	0	0	0	77
1999	56	75	1	3	0	135
2000	19	14	1	0	0	34
2001	52	33	0	1	0	86
2002	52	58	2^	0	0	112
2003	60	79	0	0	1	140
2004	68	42	6	0	0	116
2005	80	11	10	0	0	101
2006	55	30	8	0	2	95
2007	96	33	0	0	0	129
2008	251	15	7	0	0	273
2009	n/a	19	Approx 12^^	n/a	n/a	n/a

n/a – Data not available
^Three communities if additional installations in Vunivao are included.
^^ Approximately 600 SHS were installed in Vanua Levu in 2009. The number of communities this included is not clear, however assuming an average of 50 households in each community, approximately 12 communities would have been electrified.

Source: Department of Energy (2000), Government of Fiji (2006; Government of Fiji 2007a; Government of Fiji 2008), Matakiviti and Pham (2003), Interviews with Department of Energy Staff (2009 and 2010), Department of Energy Database

It is also clear from 1993-2002 data shown in table 5.3.1c that in many cases applicants for rural electrification have listed FEA connection as their preferred option, but that this has not been viable due to distances of rural communities from the electricity grid. The table shows that prior to 2002, more diesel schemes were installed than FEA grid extensions (this changed after 2002). Nevertheless, a considerable majority of applicants sought connection to the FEA grid as their preferred option.

Table 5.3.1c. Rural Electrification Projects by Preferred and Installed Technology, 1993-2002

Technology	Number of Applications for Schemes*	Number of Schemes Installed
FEA Grid Extension	682 (72%)	260 (46%)
Diesel	192 (20%)	282 (50%)
Solar	40 (4%)	13 (2%)
Hydro	27 (3%)	5 (1%)
Unspecified	12 (1%)	n/a
Government Station	n/a	2 (1%)

Source: Matakiviti and Pham (2003)
*Average of 45 households connected in each scheme.

Off-Grid Electrification

The majority of off-grid electrification projects implemented to date have involved the installation of diesel generators to power a village. This is despite the *Rural Electrification Policy's* subsidisation of upfront capital costs, which actually favours renewable technologies with high upfront capital costs and low operation or fuel costs.

There are a number of reasons for this preference among rural households. The most important seems to be the relative upfront cost of different technologies. The upfront cost of an installation is an important consideration among cash-poor rural communities, which commonly find the initial cost of solar technology prohibitive (GEF-UNDP 2002, Interviews with Department of Energy staff, July 2009; Lemaire 2009). This explains past preference for diesel systems over solar systems under the *Rural Electrification Policy* (Matakiviti and Pham 2003). Data on the upfront costs of solar systems and diesel generators supplied by the Department of Energy are provided in table 5.3.1d. Households have in the past paid 10 per cent of this cost, which equates to FJ$273.70 for a diesel system and FJ$406.50 for a solar system.

Table 5.3.1d. Capital Cost of Solar and Diesel Systems Installed by the Department of Energy

	Diesel schemes	Solar Home Systems
Average Cost Per Household (2009 FJD)	2,737	4,065

Source: Diesel costs are calculated from the Department of Energy database of installed schemes.[105] Costs of solar systems were provided by Department of Energy staff.

The importance of upfront costs to rural households also explains the recent increase in demand for solar home systems (SHS) under the *RESCO Program*. Demand for SHS under the *RESCO Program* is now higher than demand for diesel generators under the *Rural Electrification Policy* (Interviews with Department of Energy staff, July 2009). This dramatic shift has occurred because the *RESCO Program* requires only a FJ$50 deposit from households for installation (as discussed in the next section).

Upfront costs are important to rural households for a number of reasons. Low incomes and savings are the most obvious.[106] Also important is the common good features of many installed off-grid systems; an issue discussed in chapter six. Barriers to meeting upfront costs of off-grid systems are compounded by the limited availability of credit to the rural poor. Access to the formal credit market is difficult for rural households in Fiji because they generally do not have assets that can be placed as collateral. Land is the most significant asset for the indigenous population and cannot be used as collateral due to customary land tenure.

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[105] The average cost of diesel systems is calculated from a sample of 126 schemes installed or applied for in 2005 and 2006. The cost per household has been converted to 2009 Fiji Dollars. The figures are slightly higher than the costs estimated by previous reports on rural electrification in the region. For example, Woodruff (2007) estimated that the capital cost of a diesel scheme would be $2,318 FJD per household ($2,591 in 2009 FJD). This assumes the system supplies 40 households, with the generator costing $36,000 (a 36kW system at $1,000 USD per kW) and wiring costing $15,000 USD.

[106] The lack of savings among rural households is documented by the *Household Income and Expenditure Survey* (2002-03). Savings rates among rural indigenous Fijians households are lower than among rural Indo-Fijian households. This is commonly attributed to cultural obligations under the *kerekere* system and the social security provided through village kinship networks (these social obligations, explained in more detail in chapter six, provide households with a form of social security, which acts as a disincentive to save or provide for the future (Rutz 1978)).

Another factor in household choice of technology has been the services provided by the technology. Differences between Solar Home Systems (SHS) and diesel generators installed under government rural electrification programs in Fiji include:

- SHS provide power for one household whereas diesel generators power a whole village. This means that SHS are the only cost-effective option available for off-grid areas where households are geographically dispersed; as is the case for Indo-Fijian settlements in Fiji (electricity from individual household petrol generators is more expensive);
- SHS charge a battery that can be used at any time. Village diesel generators on the other hand are generally run for several hours at a fixed time each night;
- SHS installed by the Department of Energy are designed to provide lighting and in some cases power a small transistor radio. They are not designed to power other electrical appliances.[107] Diesel generators on the other hand can power appliances, although in the surveyed villages, power-hungry appliances such as refrigerators and irons would overload the system.

Other factors that influence household choice of technology include risk aversion (which is especially low among indigenous Fijians as a result of the *kerekere* system) and a lack of information about the benefits and costs of different technologies. These issues are discussed later with reference to fieldwork data collected as part of this research.

[107] Direct Current (DC) is provided by solar home systems, meaning they cannot power standard appliances without the installation of an inverter to convert Direct Current to the required Alternating Current (AC). In addition, SHS installed by the Department of Energy would need to be larger (and more expensive) in order to power electrical appliances.

5.3.2 The Renewable Energy Service Company (RESCO) Program

The *Renewable Energy Service Company (RESCO) Program* was established in order to promote solar-based rural electrification in Fiji, following the preference of households in off-grid areas for diesel systems under the *Rural Electrification Policy*.[108] The *RESCO Program* allows households to lease government-owned SHS through payment of a monthly fee. Each SHS consists of two 50W panels, a 12V Battery and a prepayment meter/controller (Interviews with Department of Energy staff, August 2009). The Department of Energy pays a private sector RESCO to provide maintenance to the systems, delivering spare parts when required. Households pay no additional money for repairs to their SHS.

The Context for the RESCO Program

Past solar-based rural electrification in Fiji provides the context for the development of the *RESCO Program*. Solar photovoltaic systems have for some time been promoted as a cost effective means of rural electrification where donors pay for the capital cost of equipment - in Fiji, other Pacific island countries, and the rest of the developing world. Solar home systems have several advantages over other technologies for the electrification of rural areas where extension of the electricity grid is unlikely in the near or medium term. First, their respective life cycle costs are generally lower than those of "traditional" lighting sources used in developing countries, such as paraffin lamps, and are comparable to those of diesel or petrol generators (although diesel generators have a lower upfront capital cost) (Woodruff 2007; World Bank 2006b). Second, SHS are modular in nature, which makes them suitable for rural areas, where demand for electricity is low, while providing households with the option of expanding their system size as demand for electricity increases (Best 1992). Third, SHS are particularly suited to areas where irregular and

[108] The program has its origins in a project run by the US-based Pacific International Center For High Technology Research (PICHTR) and funded by the Government of Japan in Bua province, on the western side of Vanua Levu. The Global Environment Facility also provided funding. Several years after its inception, the project was transferred to the Department of Energy, which expanded the program to the whole of Vanua Levu. The sole technology installed by the *RESCO program* is solar-based, although it was noted in the design and an accompanying *Charter for Renewable Energy Based Rural Electrification with Participation of Private Enterprises* (2003) that a similar model could be established for the maintenance of village diesel generators.

unreliable transportation poses a problem for the importation of fuel or spare parts for generators (Best 1992; Jafar 2000; Martinot 2003; REN21 Renewable Energy Policy Network 2005). These advantages are highly relevant for rural communities in Fiji and other SIDS.

Despite its advantages, adoption of solar technology has been slower than was once hoped, and its performance around the world has been mixed (Nieuwenhout, et al. 2000; Nieuwenhout, et al. 2001). Several barriers to the diffusion of SHS in developing countries have required interventions by governments or donors to promote the technology. These barriers can be broadly placed into two categories:

1. High upfront costs of SHS

   Upfront costs for SHS are significantly higher than for diesel generators, although lifecycle costs are similar (upfront costs were shown in table 5.3.1d) (Woodruff 2007; World Bank 2006b). As a result, rural households with low incomes often find the initial cost of a SHS prohibitive (Lemaire 2009). This barrier is compounded by the limited availability of credit to the rural poor.

2. Low service standards

   Poor maintenance has affected SHS throughout the developing world (Nieuwenhout, et al. 2001; van der Vleuten, et al. 2007; Wade 2003). In the Pacific islands, it is now generally accepted that although early SHS failures were due mainly to technical problems with untested equipment, failures in the last two decades have been more the result of inadequate maintenance, underlying which has been a failure of institutional structures created to maintain such systems (Bygrave 1998; Johnston, et al. 2005; Liebenthal, et al. 1994; Wade 2005b). The remoteness of communities where SHS are installed has compounded maintenance problems.

Interventions by donors and governments have sought to support and subsidise SHS in response to these barriers. Measures include:

- *Donations of SHS* by governments or donors. These were common in the early stages of SHS development, and were based on the assumption that the technology was unaffordable to rural households in developing countries. Projects commonly involved the provision of hardware only, with very little expenditure on training and institutional arrangements for SHS maintenance (Nieuwenhout, et al. 2000; Nieuwenhout, et al. 2001; Outhred, et al. 2004; Tukunga, et al. 2002). This resulted in projects that were not sustainable, with poor maintenance and a failure to collect fees for the replacement of SHS components.

- *Provision of consumer credit* for SHS. Provision of credit can overcome the upfront cost barrier to SHS deployment, while retaining user commitment to SHS maintenance. Credit systems generally involve the provision of seed finance or financial guarantees by a donor or government body. The success of such schemes has been mixed, as they do not address the need to ensure that good quality systems are installed and maintenance is available (Nieuwenhout, et al. 2000; Nieuwenhout, et al. 2001).

- *Fee for service* models, which are increasingly popular and can take various forms. The common feature of such models is that a company or utility provides rural households with a SHS for a fixed monthly fee. Nieuwenhout et al. (2001) argue that fee for service schemes have the potential to overcome the two big barriers to SHS deployment, by spreading the high upfront cost of SHS over several years, and ensuring the provision of maintenance. However they also caution that there is not enough empirical evidence to judge the success of fee for service models.

The establishment of institutional arrangements for maintenance and fee collection (to pay for maintenance) remains the biggest challenge for SHS projects. There is an emerging consensus that no one model is suited to all circumstances. Each model has its advantages and disadvantages, with its appropriateness depending on the economic, social, cultural and institutional features of the region where it is installed (Nieuwenhout, et al. 2000;

Nieuwenhout, et al. 2001; Outhred, et al. 2004; Urmee and Harries 2006; van der Vleuten, et al. 2007; Wade 2003).[109]

Development and Expansion of the RESCO Program in Fiji

In Fiji, donor funding of solar-based rural electrification projects has resulted in experience with several of these models. The first solar projects were put in place in 1983, when three villages had SHS installed under a donor model, with limited government assistance. These systems faced many technical problems and none of the original systems is now in operation. In 1994, two pilot programs based on the donor model had more success, as they involved more government assistance in maintenance provision. However these programs were heavily subsidised and could not be repeated at a nationwide level (GEF-UNDP 2002; Johnston, et al. 2005). There has also been some market-based provision of SHS in Fiji, although low rural incomes and geographical features have limited the size of this market.

More recently, solar systems have been installed under the *RESCO Program*, which is a fee for service model.[110] In the design of the *RESCO Program*, it was acknowledged that an important reason for the low adoption of SHS under the *Rural Electrification Policy* was that the upfront cost to applicants for diesel systems was lower than for SHS, notwithstanding the government subsidy (GEF-UNDP 2002; Matakiviti and Pham 2003). The *RESCO Program* therefore sought to reduce the upfront cost of SHS. It did this by maintaining Department of Energy ownership of installed SHS, thereby lowering the cost to consumers. Households lease the SHS for a FJ$14 monthly fee that is paid to the Department of Energy, through the local post office (which takes a FJ$0.50 commission). The Department of Energy pays a RESCO FJ$10 per month for maintenance of each SHS, with the remaining money being used for purchases of replacement components for SHS

[109] It is also worth noting that the identification of a successful model for SHS in a country is a historical process that involves trial and error. This points to the advantages of channelling donor funds through existing institutional arrangements (and making adjustments to those arrangements when problems are identified), rather than establishing new projects (Nieuwenhout, et al. 2000; Nieuwenhout, et al. 2001). In the Pacific islands this point is highly relevant, as the large amounts of donor aid to GDP generally results in piecemeal projects that lack local ownership.

[110] The term "RESCO" as used in Fiji is misleading, as under a true RESCO model, the RESCO would own the systems and collect money directly from users. The model used in Fiji seems to have more in common with a public-private sector partnership, as government is involved in sourcing spare parts and collecting money. The term RESCO is used in this research in keeping with its use in Fiji.

(such as batteries). When customers pay their monthly fee at the local post office, they are given a token or code that is entered into the prepayment meter of the SHS.[111] Where the code/token is not entered, the prepayment meter shuts down the SHS, preventing the households from accessing electricity. The only upfront cost paid by households is an initial deposit of FJ$50.

The program has met its goal of increasing demand for SHS, with demand under the *RESCO Program* so high that there exists a long waiting list of applicants (Interviews with Department of Energy staff, July and November 2009).[112] Department of Energy staff indicated that demand for SHS under the *RESCO Program* has come at the expense of applications for diesel generators. This is reflected in statistics provided by the Department, which show a fall in the number of diesel generator installations (15 diesel systems were installed in 2008, compared to an annual average of 41 since 2001). In comparison, of the 1,600 SHS installed under the *RESCO Program*, approximately 600 systems were installed in 2009. To date, the *RESCO Program* has been restricted to the island of Vanua Levu, however it is now set to expand as a result of demand from other areas of Fiji, with the Department of Energy opening it to off-grid rural households across the country (in July 2010 the Department of Energy stated it was issuing a tender for the installation of 1,000 new systems).

Existing fees charged to households under the *RESCO Program* involve a subsidy from the Department of Energy. The monthly fee paid by households is not sufficient to pay for ongoing maintenance costs, let alone repay any of the capital cost of SHS (at least 5 per cent should be repaid under the *Rural Electrification Policy*, under which the *RESCO Program* is said to fall by Department of Energy management). Although the Department of Energy could not provide current figures, a detailed commercial and economic evaluation of the viability of the *RESCO Program* in 2003, estimated that monthly maintenance costs would be FJ$15.33 (in 2009 $FJ) (Wade, et al. 2006). The actual cost of maintenance to the Department, including RESCO profit, is approximately FJ$18.72. This is shown in table 5.3.2a. This figure is higher than the FJ$14 currently paid by customers,

[111] This depends on the prepayment meter that has been installed.
[112] In July 2010, there was a waiting list of approximately 1,000 that had paid the $50 FJD deposit for a SHS and were awaiting installation.

threatening sustainability of the *RESCO Program* if government does not fund Department of Energy subsidisation of the program. This is currently the case, as discussed in chapters six and seven.

Table 5.3.2a. Cost of Maintenance of Solar Home Systems under *RESCO Program*

	2003 Transenergie Estimate (2009 $FJ)	Actual Cost ($FJ)
Replacement Batteries (every 42 months)	5.57	Not Known (2003 estimates are used here)
Replacement Lights (every 36 months)	2.64	Not Known (2003 estimates are used here)
Technicians	6.48	10 (paid to the RESCO)
Fiji Post Commission	0.63	0.50
Total	15.33	18.72

In summary, most rural electrification schemes to date have involved extension of the FEA electricity grid. Diesel-based generation has been the most commonly used technology for off-grid electrification. Solar technology has also become important in recent years, albeit at a heavily subsidised rate that goes beyond that set by the *Rural Electrification Policy*. This study focuses on diesel and solar technology when looking at off-grid electrification technologies, given that these two technologies are the most common form of off-grid electrification in Fiji.[113]

5.4 Fieldwork

Fieldwork involving interviews, focus group discussions, and a survey, was carried out as part of this research. The objective in collecting this data was to:

- Identify threats to security of electricity supply in rural areas;

[113] Mini and pico-hydro-power systems are not considered due to the small number installed to date in Fiji, their highly variable cost (which is very location specific), and the fact that a hydro-power resource is available in only a small proportion of rural communities.

- Explore the impact of high fuel prices on rural households;
- Assess institutional frameworks for operation and maintenance of generation equipment; and
- Compare the financial implications of electrification for rural households using different generation technologies.

Collection of data was considered necessary due to a lack of existing data on these issues. An overview of existing data and gaps in research is provided in Appendix A5.1. Fieldwork was carried out in Viti Levu (mainly in Suva) in July-August and November-December 2009, and in Vanua Levu in November-December 2009. The results from the fieldwork in Vanua Levu are the focus of this chapter. This section details how and where fieldwork was conducted, and provides an overview of the communities that were surveyed. The section that follows describes the findings of that fieldwork.

5.4.1 Overview of the Fieldwork Area

Identification of the Fieldwork Area

Four communities in Bua province were selected for fieldwork, based in part on advice from the Department of Energy. This is one of the few areas in Fiji where there are long-standing diesel and solar-based rural electrification projects in neighbouring communities (Interviews with Department of Energy staff, November 2009). Two communities surveyed are supplied electricity through a mini-grid system connected to a diesel generator, while two other communities have SHS installed in households. The selection of these fieldwork sites enabled a comparison of the two technologies. The communities were selected for several reasons:

Inclusion in previous surveys – Three of the four communities surveyed had been included in the 2005 *Rural Electrification Survey* conducted by the Department of Energy. It was hoped that surveying the same group of people would enable this survey to generate time series data. Unfortunately, no indigenous Fijian village with SHS was surveyed in the 2005 *Rural Electrification Survey*. Nakawakawa was instead surveyed as it had been included in another study (Gonelevu 2006).

System Age – Communities that were surveyed had off-grid systems that were installed some years ago, so that the impact of maintenance arrangements on security of supply could be assessed. Both diesel generators in Dama and Wairiki were installed in the early 1990s, while the SHS in Vunivao were among the first systems installed under the *RESCO Program*, with most installations occurring in 2000-02. The SHS in Nakawakawa were relatively new, having been installed in 2005 and 2006. This was nevertheless one of the first indigenous communities where SHS were installed under the *RESCO Program*.

Ethnicity – It was deemed important to include both an Indo-Fijian and an indigenous Fijian community with SHS in the survey, owing to the very different profiles of these communities. No diesel generators have been installed in Indo-Fijian settlements under the *Rural Electrification Program* (Interviews with Department of Energy staff, July and November 2009), meaning that only indigenous Fijian villages connected to diesel generators were surveyed.

Personal Connections – Department of Energy staff members were visiting the area at the time and were able to introduce us and our research project.[114] This was important in ensuring acceptance of the project and our visit, as well as allowing us to formally request permission from community leaders to visit the communities (which was especially important in indigenous Fijian villages, as described below).

Logistics – The survey sought to look at areas that were some distance from urban centres, but at the same time were sufficiently accessible that fieldwork could be conducted in a limited timeframe. The four locations selected were relatively near to one another, allowing travel from one centre to the other within a short period (4 hours was the maximum time

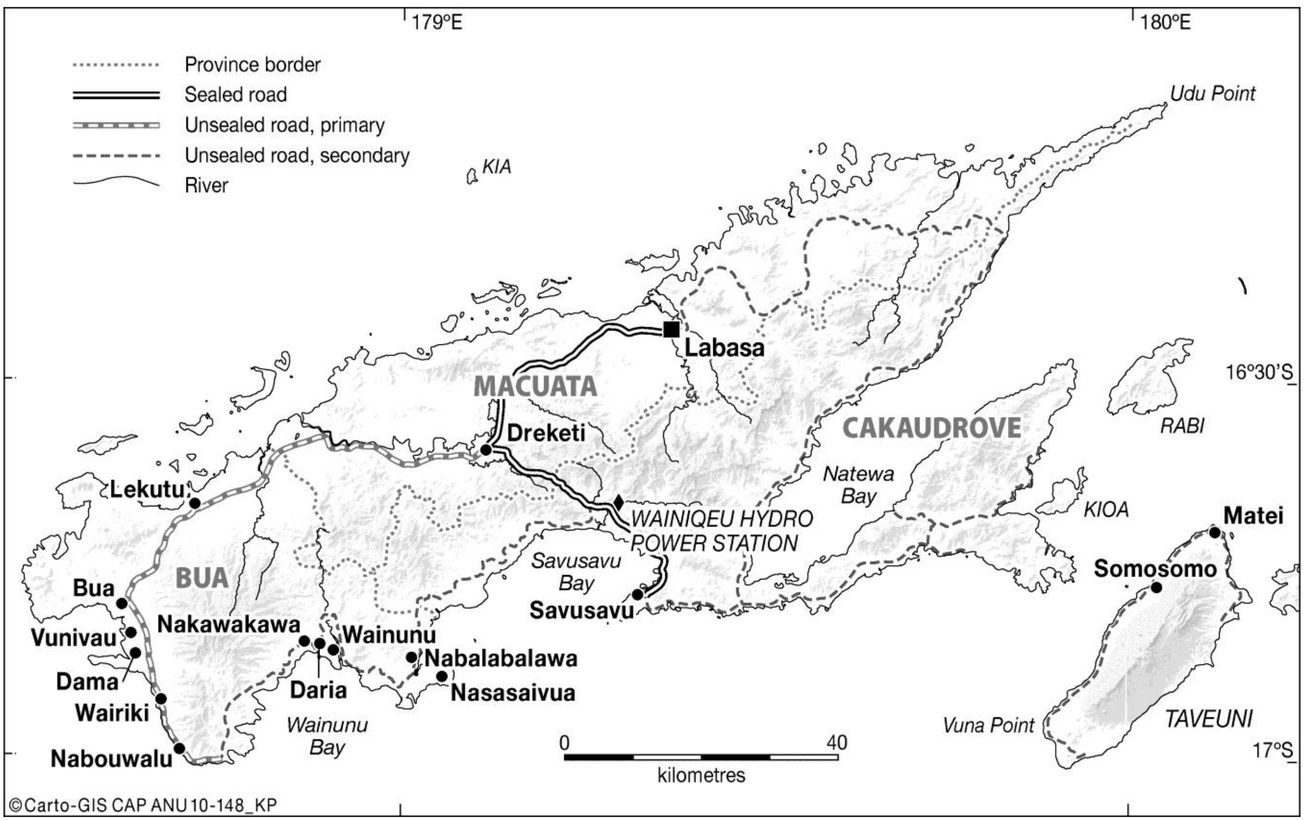
[114] A Fijian friend of mine from Suva, Eferemo Campbell Romokosoi, agreed to assist my research by acting as an interpreter and was paid for his work. This was deemed necessary, as I do not speak Bau Fijian and many villagers do not speak English (or do so only poorly).

travelled between two centres). At the same time, the nearest urban centre (Labasa) was some distance from any of the locations.

Overview of Bua Province

The four communities selected for the fieldwork are situated in Bua province, on the western side of Fiji's second biggest island, Vanua Levu (see figure 5.4.1a). Bua province has a total population of 14,176 according to 2007 census data, 11,183 of whom are indigenous Fijians and 2,366 of whom are Indo-Fijians (Fiji Islands Bureau of Statistics 2007). Most Indo-Fijians reside in the northern part of Bua province, in an area called Bua (where Dama and Vunivao are situated). The population in the southern parts of Bua province such as Vuya and Wainunu (where Nakawakawa is located) is populated primarily by indigenous Fijians (Government of Fiji 2005; Walsh 2006).

Figure 5.4.1a. Map of Vanua Levu



Source: Cartography Department, ANU

The distinction between the two ethnicities is important, as the livelihoods of each group differ. The livelihoods of indigenous Fijian villages in Bua province are based on a mixture of subsistence agriculture to meet food requirements, and cash cropping to meet financial expenses, such as basic education and fuel. Production of dalo (taro), cassava, various yams and other root crops are an important source of nutrition.[115] Data from the 1996 census confirm that Bua province had among the highest proportion of households depending on subsistence employment of any province in Fiji (Walsh 2006).[116] The sale of these crops and kava also form the main source of cash income in indigenous households. Seafood is also occasionally sold, although transporting fresh produce to markets is difficult given the lack of access to refrigeration.

Indo-Fijian households in Bua province are generally more integrated into the cash economy and therefore have higher cash incomes than indigenous Fijian households (Government of Fiji 2005). Indo-Fijian households grow cash crops for sale in the marketplace, especially rice and tobacco. Sugar cane is also grown in Bua province, although it is not so prevalent as in other parts of Vanua Levu closer to the Labasa sugar mill. Indo-Fijians are also more commonly involved in non-agricultural business in Bua province than are indigenous Fijians, dominating the carrier (or four wheel drive taxi) business and other retail businesses.

Bua province is the poorest province in Fiji. The incidence of poverty in Bua province was 63 per cent in 2002-03, as measured by the proportion of the population living below the national Basic Needs Poverty Line (BNPL).[117] This compares to a national incidence of poverty in 2002-03 of 35 per cent (40 per cent in rural areas), as shown in table 5.4.1a (Fiji

[115] Hooper (2000) notes that use of the term "subsistence" for Pacific island communities can be misleading, as "subsistence" livelihoods rely on a set of interrelationships and mutual obligations between households and identity groups. These relationships are described in more detail in chapter six.
[116] The 2007 census does not provide occupational data at the provincial level.
[117] The Basic Needs Poverty Line (BNPL) in 2008-09 established a minimum weekly income for households with four adult equivalents at FJ$186.15 in urban areas, and FJ$164.60 in rural areas (Fiji Islands Bureau of Statistics 2010b). The poverty line is calculated using the Food Poverty Line and the Non-Food Poverty Line. The Non-Food Poverty line focuses on essential non-food expenditure while the Food Poverty Line reflects expenditure on food which is minimally nutritious, meeting the 2100 kcal per day minimum food energy needs of an adult. Necessary expenditure on food used to calculate the Food Poverty Line differs between rural and urban populations, in recognition of the important role that subsistence agriculture plays in providing food security for rural households.

Islands Bureau of Statistics 2010a). The northern division within which Bua province is located is also the poorest division in Fiji.[118]

Table 5.4.1a The Incidence of Poverty in Fiji (Percentage of the population below the BNLP)

	Data from HIES 2002-03	Preliminary Data from HIES 2008-09
Fiji (total)	35	31
- Urban Fiji	29	19
- Rural Fiji	40	43
Divisions of Fiji		
- Central Division	26	21
- Western Division	37	33
- Northern Division	53	48
- Eastern Division	35	38
Provinces in the Northern Division		
- Macuata Province	50	n/a
- Cakadrove Province	51	n/a
- Bua Province	63	n/a

Note: Figures specific to provinces from the 2008-09 HIES were still to be released at the time of writing.

The use of low income case studies in this research provides insights into appropriate choice of rural electrification technologies for un-electrified households. The majority of un-electrified households in Fiji also have low incomes, with wealthier households purchasing small households generators for their electricity needs. This research project is therefore particularly relevant to government policy in Fiji, which has set a target of 100 per cent electrification in Fiji by 2016. The implications of this target are discussed in chapter seven.

[118] The high incidence of poverty in the Northern Division has resulted in a "Look North" policy that has been continued by successive (democratic and military) governments, with tax breaks and various other measures designed to attract investment to the north. Preliminary figures from the 2008-09 *Household Income and Expenditure Survey* show some progress, with the proportion of the population in the northern division below the Basic Needs Poverty Line falling from 53 per cent to 48 per cent (although it was 51 per cent in rural areas). Although an improvement, this remains significantly higher than the national figure of 31 per cent, and is attributed in part by the Government to migration from poor rural areas in Vanua Levu to urban areas in both Vanua Levu and Viti Levu (Fiji Islands Bureau of Statistics 2010b).

Overview of the Surveyed Communities

The communities that formed part of this research project were: Wairiki, Dama, Vunivao, and Nakawakawa. Three of the four communities (Wairiki, Dama and Vunivao) are near to the Nabouwalu Road, which is the major road link between Labasa and the Nabouwalu wharf, where most traffic between Suva and Labasa travels.[119] The unsealed road is in good condition and can be travelled most of the year, although rain associated with cyclonic activity does occasionally make it impassable. Travel to Labasa normally takes approximately 3-4 hours. The government centre of Nabouwalu is much closer to these communities, and consists of a small government district office, a hospital and the wharf at which ferry services linking Suva and Labasa dock. The north and west of Bua province, where these three communities are situated, is fairly dry.

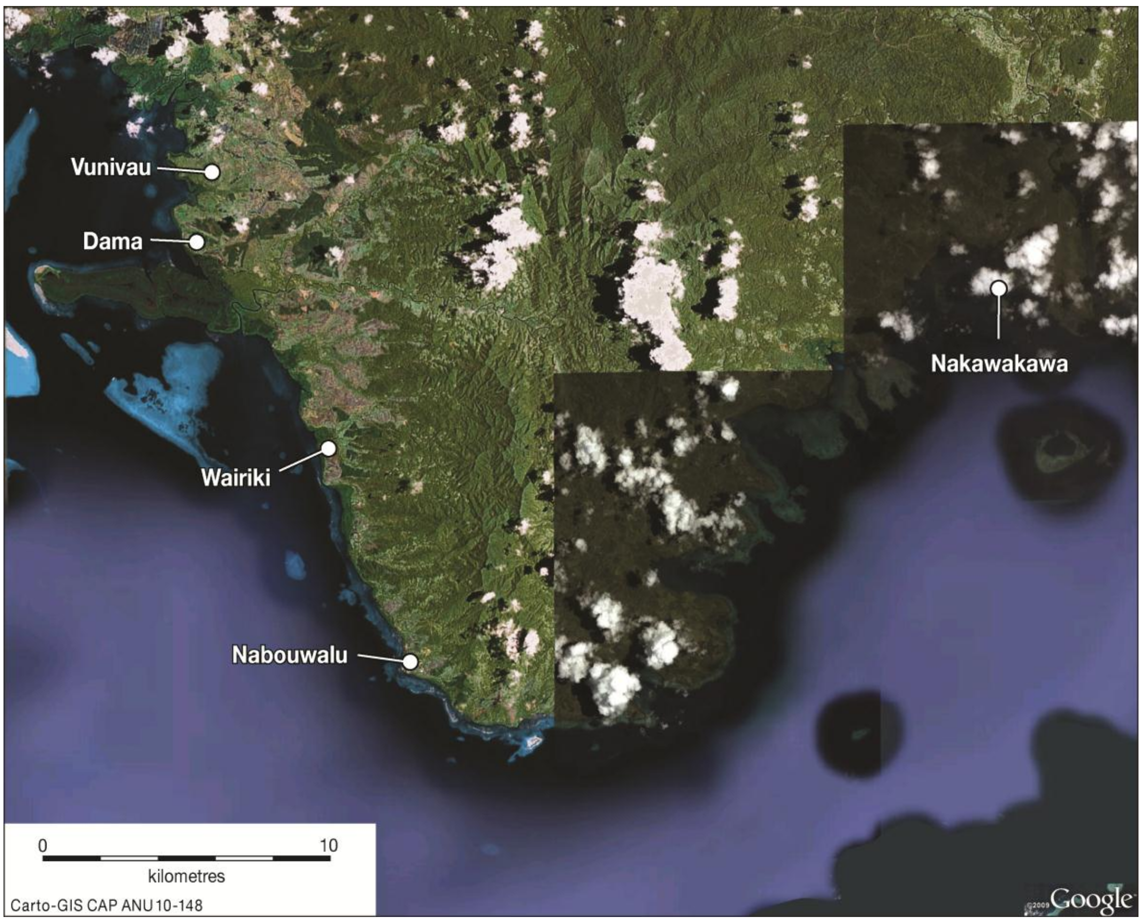
Nakawakawa is more isolated than the other three communities, being some 40 kilometres from Nabouwalu. This takes 3 hours and 30 minutes by bus on a very poor dirt road. This road continues to the east to the urban centre of Savusavu, but is in such a poor state beyond Daria (5 km from Nakawakawa) that it is unfit for public transport. The nearest urban centre by road for practical purposes is therefore Labasa, which can be accessed through Nabouwalu in a trip taking approximately 7 hours. Nakawakawa is also near to Daria, where a small medical centre and post office are located. The southern part of Bua province, where Nakawakawa is situated, is a much wetter environment than that of the other surveyed communities.

The features of these communities vary. The two communities with diesel generators are located near to one another (see figure 5.4.1b for a satellite image). Wairiki is a small indigenous Fijian village of 19 households, situated on Nabouwalu Road about 20 minutes by bus from Nabouwalu. Dama is a larger indigenous Fijian village, with 33 households. It is situated about a 10 minute walk from the Nabouwalu Road and 40 minutes by bus from

[119] Labasa is the biggest town in Vanua Levu, as outlined in chapter one. Although it has a population of only 7,700, peri-urban areas around Labasa increase the population of greater Labasa to 28,000 (Fiji Islands Bureau of Statistics 2010a). Labasa is also the administrative centre of the Northern division of the Fiji Islands.

Nabouwalu. It is also near to the Indo-Fijian settlement of Vunivao and next to a smaller village, Nasau. Both Dama and Wairiki have a diesel generator that provides electricity to most houses (17 houses in Wairiki and 23 houses in Dama) through a mini-grid system. These systems were installed by the Department of Energy under the pre-1993 *Rural Electrification Policy*, in 1992 in Wairiki and 1991 in Dama. In Wairiki, fuel is normally purchased from Nabouwalu petrol station. In Dama, fuel is normally purchased directly from a shop owned by the chief of Dama village.[120] This fuel business sells kerosene, diesel and pre-mix fuel at prices higher than those allowed by the Prices and Incomes Board.[121]

Figure 5.4.1b Satellite Image of Survey Area



Source: Cartography Department, ANU

[120] The chief has a fuel vendor license, and organises for a petrol station in Labasa to deliver 200L drums of diesel, kerosene and pre-mix fuel to his house.
[121] By law, fuel must be sold in Fiji at prices set by the Prices and Incomes Board (a function recently transferred to the Commerce Commission). In isolated rural areas however, fuel is frequently sold for prices above those set by the Prices and Incomes Board.

The two surveyed communities with SHS are very different. Vunivao is an Indo-Fijian settlement of approximately 144 households. It extends over several kilometres, with each house situated next to its own farm land. This includes both land leased from indigenous Fijian landowners and freehold land. Vunivao is also near to Nabouwalu Road, and is several kilometres from Dama village. SHS were installed in most households in Vunivao as part of the *RESCO Program* in 2000-01.

Nakawakawa is a relatively large but concentrated indigenous Fijian village, with 63 households. Approximately 28 of these households have had SHS installed under the *RESCO Program*; 21 in a first wave of installations that occurred in 2005-06, and seven more that were installed in 2009. Maps of all four communities are provided in Appendix A5.2.

A brief description of the four communities is provided in table 5.4.1b.

Table 5.4.1b. Overview of the Four Surveyed Communities

	Wairiki village	Dama village	Vunivao settlement	Nakawakawa village
Electrification Technology	Diesel Generator	Diesel Generator	SHS	SHS
Date systems installed	1992	1991	2000-2002	2005
Ethnicity	Indigenous Fijian	Indigenous Fijian	Indo-Fijian	Indigenous Fijian
Size	19 households	33 households	144 households	63 households
Driving time from Labasa (nearest urban centre)	3 hours 15 minutes	3 hours	3 hours	7 hours
Driving time from Nabouwalu	15 minutes	40 minutes	40 minutes	3 hours 30 minutes
Livelihoods	Subsistence agriculture, sale of dalo, kava and seafood in Nabouwalu and Labasa	Subsistence agriculture, sale of dalo, kava and seafood in Nabouwalu	Cash cropping, including rice and tobacco. Some subsistence agriculture among poorer households	Subsistence agriculture, sale of dalo kava, and seafood in Nabouwalu
Land status	Native land owned by village *mataqali**	Native land owned by village *mataqali*	Mainly freehold land owned by households. Some leases of native land.	Native land owned by village *mataqali*

* The term "*mataqali*" refers to a landowning kinship group in Fiji, and is explored in chapter six.

Livelihoods in the four communities surveyed are primarily linked to agriculture. In the indigenous Fijian villages, the majority of food consumed is grown by households, indicating a reliance on subsistence agriculture. Staple crops include dalo, cassava, and various yams. Households also sell dalo, kava and seafood in Nabouwalu. A middleman operating in Wairiki refrigerates seafood, allowing it to be sold in Labasa.

Livelihoods in the Indo-Fijian community of Vunivao involve cash cropping of rice, tobacco and (to a lesser extent) sugar cane. Households normally also have their own gardens to grow food for consumption.

Information on income in these communities was difficult to obtain. Households were not questioned about their incomes in this research project, as a result of advice from Department of Energy staff and the Fijian interpreter (survey data regarding household income in rural Pacific island communities are also generally unreliable; see Allen (2007)).[122] Data on incomes are instead taken from a number of sources, the most important being an ADB-funded Government survey of households near to Nabouwalu Road in Bua province (the location of three communities surveyed in this research project) (Government of Fiji 2005). The data show that a majority of indigenous Fijian households (69 per cent) in the area where fieldwork occurred had an income below FJ$50 FJD per week, compared to 36 per cent of Indo-Fijian households. Average incomes were also higher among Indo-Fijian households in the area, as shown in table 5.4.1c. The report notes that Indo-Fijians generally had more diverse sources of income than indigenous households, supplementing farm income with work in shops, as mechanics, and teachers (Government of Fiji 2005). This data are presented in more detail in Appendix A5.3.

Table 5.4.1c. Total Weekly Household Income from all Sources: Survey Sample in Bua Province (per cent of surveyed households)

	Indigenous Fijian Households	Indo-Fijian Households
Less than FJ$50 per week	69	36
FJ$50-100 per week	21	24
FJ$100-200	7	23
FJ$200-300	3	17
Over FJ$300	0	0

Source: Government of Fiji (2005)

The higher cash incomes recorded among Indo-Fijian households do not necessarily equate to higher standards of living. Indo-Fijian households earn higher cash income but must also spend more of their income on basic foodstuffs. They do not have the same social safety net available to indigenous Fijians through kinship networks, or the same access to land to

[122] The survey originally included a question on household income, consistent with previous surveys administered by the Department of Energy. This information would have been useful as it could be used to assess spending on energy as a proportion of total cash income. However, the Fijian interpreter involved in administering the survey and several Department of Energy personnel advised against asking about household income, arguing that it would be considered intrusive and would make respondents feel uncomfortable, possibly affecting answering of other questions. The question was withdrawn from the survey as a result.

grow food for subsistence use. Poverty as experienced by Indo-Fijian households is therefore also different from that experienced by indigenous Fijian households.[123]

In the absence of survey questions relating to income in this research project, the state of each house and its contents was observed in order to generate some indication of the relative wealth of each household. Households were listed as being either above average income households, average income households, or below average income households, based on the appearance of the house and its contents as compared to other houses in the four surveyed communities. Notes with the interpreter were compared after each interview to improve these subjective assessments. The results are used below to assess energy expenditure among households of different income levels. A question about monthly household savings also gave some indication of household wellbeing. Both sets of data are provided in Appendix A5.4.

The survey also gathered data on the size and child-adult ratio of households (see Appendix A5.5). Wairiki and Nakawakawa had the largest households, although the child to adult ratio in households from each community was very different. There was almost one child for every adult in the village of Wairiki, while there were relatively few children in Nakawakawa. This may reflect the distance of schooling from each community (unlike the other communities, Nakawakawa was not near a high school). In Dama, the population was noticeably older with smaller household sizes.

[123] The ADB-funded survey report (2005) notes that Indo-Fijian households with an income below FJ$50 per week were generally worse-off than indigenous Fijian households with the same income, as they did not own land or have the same kinship networks available to indigenous Fijians. The report noted that many members of Indo-Fijian households in the bottom 36 per cent of households earn less than US$1 per day; a figure (now updated to US$1.25) considered to represent extreme poverty by the international community.

5.4.2 Conduct of the Fieldwork

Introductions

Department of Energy staff introduced me and my interpreter to the communities where the fieldwork was to occur in November 2009. These introductions carried some risk that we would appear to communities to be working for or associated with the Department of Energy (potentially prejudicing their answers). In these meetings it was therefore made clear that my research was independent of the Department, a message that was repeated in every household surveyed.

In the indigenous Fijian villages, introductions occurred through a *sevusevu*, which is a ritualistic offering of kava used to ask permission of a village chief and village ancestors for an activity or visit.[124] Once the s*evusevu* was accepted, my intentions of visiting without Department of Energy personnel in the following weeks were communicated, and the protocol and logistics of the visits were organised. In the Indo-Fijian community of Vunivao, introductions occurred through a less formal process, beginning with a meeting with the headmaster of the local school. He introduced us to other community leaders who were involved in the installation of SHS, most of whom held a position in the local Red Cross society. A work plan for fieldwork in Vunivao was developed with their assistance.

Survey Sample

Approximately 20 households from each of the four communities were surveyed as part of the research project. This formed different proportions of the population of each community, which vary in size. This is illustrated in table 5.4.2a.

[124] This offering was considered very important among both villagers and Department of Energy staff, and no fieldwork in the villages could have been conducted without it. See Turner (1987) for a description of *sevusevu*.

Table 5.4.2a Survey Sample in Each Community

	No. of households surveyed	No. of households in the community	Percentage of households surveyed
Wairiki	17	19	89
Dama	20	33	61
Nakawakawa	21	63 (28 electrified)	33 (or 75 per cent of households with SHS)
Vunivao	20*	144	14

* Four of these operated businesses, and are excluded from some of the tables due to their much higher energy consumption.

On our arrival in each village for fieldwork (having presented the *sevusevu* and explained our intentions in a previous visit), the *turaga ni koro* (or village organiser) called a village meeting explaining the purpose of our visit. A list of households that had been surveyed in the 2005 *Rural Electrification Survey* was provided to the *turaga ni koro* who then identified their location in the village. The goal was to select households (and where possible household members) previously surveyed. A selection of these households was selected at random for the survey. Efforts were also made to ensure equal representation from both genders in the survey.

In Vunivao, the mapping of households occurred in the first meeting with community leaders. In addition, a community leader accompanied us when conducting interviews and surveys, to act as interpreter where necessary (my interpreter spoke Bau Fijian, and in several households only Fijian Hindi was spoken).[125] A four wheel drive vehicle was used to move between houses, which are distant from one another. As in the indigenous villages, households were selected at random from a list of households previously surveyed by the Department of Energy (with a gender balance in participants also sought).

[125] Bau Fijian is the common language among indigenous Fijians and is taught in schools. The language is originally from Bau island off eastern Viti Levu and was used by the colonial administration to unify Fiji. In Bua province, other dialects are spoken that are generally intelligible to someone that speaks Bau Fijian, although understanding some of the words was difficult for the interpreter (who would then clarify their meaning).

Survey Questions

The survey questionnaire formed the main source of quantitative data for rural areas, and was an important component of the fieldwork. Survey questions were asked verbally, with answers then recorded by me or my interpreter. The survey was split into three sections, which were answered by different people:

a. Main questionnaire (39 questions)
   This was answered by all households and included general questions on the household; energy consumption; the use of electrical appliances; and quality, reliability and institutional arrangements governing electricity supply. Questions also addressed the impact of high fuel prices on households and compared this to the impact of high food prices in recent years.

b. Diesel generator questionnaire (18 questions)
   This was answered by the village technician and others village members responsible for operation of the generator. It covered questions about diesel generator operation times, fuel purchases, and reliability of the generator. It also addressed institutional arrangements for operation and maintenance of the generator.

c. Solar power questionnaire (11 questions)
   This was answered by all households with SHS. It explored whether households were satisfied with their SHS, willingness to pay for additional services or increased reliability, and how frequent power outages affected the system. It also asked respondents about maintenance provided under the *RESCO Program*.

The survey questionnaires can be found in Appendix A5.6.

Interviews

Interviews were held with all community members who played a role in the supply of electricity. In indigenous villages, this included key village leaders, such as the village chief, the local pastor, the village organiser (*turaga ni koro*), village committee members, the village treasurer, store or business owners, and (where applicable) the operator of the diesel generator. In the Indo-Fijian settlement of Vunivao, this list included members of the solar committee (which no longer meets), leaders of the local Red Cross branch (which now communicates concerns about SHS to the Department of Energy), the school headmaster, and past members of the multi-ethnic District Office.[126]

In addition, some survey respondents that demonstrated knowledge of energy expenditure and electricity supply were interviewed after completing the survey, in order to gather further information from them. These questions were informal and were asked as part of a free flowing conversation. They focused on institutional structures at the village level, the experience of the *RESCO Program*, household preferences in relation to electrification and energy consumption, and the impact of high food and fuel prices.

Interviews outside the four communities concerning rural electrification included meetings with Department of Energy staff, including Suva-based policy staff and technicians involved in the field, RESCO staff, District Officers responsible for government administration in Bua province, and indigenous leaders in local provincial councils.[127] Most of these discussions took place in Nabouwalu, Labasa or Suva. All interviews were semi-structured.

Focus Group Discussions

Several focus group discussions were also held as part of this fieldwork. Most of these group discussions were informal, involving discussions around a kava bowl with a group of village men, or conversations at dinner with village women. Participation in these informal conversations was determined by whoever was present at the time. Trust was first established through general discussion, enabling participants to feel more comfortable in expressing their opinions about electricity supply in their community. Group discussions were free flowing, although I ensured that the subjects included in this research project were explored. Other focus group meetings were more formal. These included meetings with the village committees and a meeting with Indo-Fijian community leaders. These

[126] The multi-ethnic District Office forms part of the provincial government in Fiji.
[127] An interview was also unsuccessfully sought with Commissioner Northern, the officer appointed by the Prime Minister in order to control government activity in the Northern Division of Fiji.

meetings were less free flowing, with the subjects discussed more firmly related to the research project (although there were some diversions based on the comments of participants). Participation in these meetings was determined on the basis of people's position and role.

5.5 Findings

This section presents results from the fieldwork in two sections. Section 5.5.1 presents energy consumption data. The section is significant as it details the impact of fuel price volatility on rural households, focusing on the different experiences of households that are un-electrified, connected to a diesel generator, or are supplied with solar-based power. This gives an indication of the financial impact of rural electrification on households. The inclusion of this section also acknowledges that the impact of fuel price volatility on off-grid power supplies cannot easily be separated from its broader impact, given the ability of households to substitute traditional lighting fuels for electricity (and *vice versa*).

Section 5.5.2 presents electricity supply and consumption data. It discusses household perspectives and spending on electricity, and the prevalence and causes of power outages. Data on institutional structures governing rural electrification are also presented. The section provides the basis for a detailed analysis of institutional structures governing rural electrification in chapter six.

5.5.1 Energy Consumption and Expenditure Data

Respondents were asked in the survey for an extensive description of household energy consumption, including volumes consumed and money spent on different sources of energy. Forms of energy consumed include a number of lighting and cooking fuels, electricity, petrol/diesel, batteries and candles. Households were also asked for expenditure on energy at the time of the survey (in November and December 2009), in 2008 (when fuel prices peaked) and in 2004 (before the large increases in fuel prices). These data provided information on the impact of high fuel prices on rural households.

Methods for Estimating Present and Past Expenditure on Energy

Several questions relating to energy consumption in the survey purposefully overlapped, thereby enabling for answers to be verified against one another. Estimates of household energy expenditure provided by respondents were unfortunately in many cases not internally consistent.[128] Assessing past expenditure on energy was particularly difficult. Many households were unable to remember prices and expenditure for previous years, reducing the sample size for these answers considerably.[129]

An alternative approach is adopted here in order to generate better data on past household expenditure. As part of the research project, the locations where fuels and other forms of energy were purchased were noted. Prices in each location were also recorded and compared to prices set by the Prices and Incomes Board.[130] These involved specified mark-ups and also transport freight costs. In some unregulated businesses that do not abide by the prices set by the Prices and Incomes Board, (unregulated and illegal) price mark-ups were high. Prices were set against the volume of each fuel (and other form of energy) consumed by the household in order to calculate household expenditure on that fuel. These figures were combined to calculate total household expenditure on energy. Estimates of the volumes of fuels consumed were generally considered more reliable than estimates of expenditure on those fuels. This is consistent with the approach of previous surveys

[128] In general, estimates of spending on an individual fuel or energy source were considered more reliable than estimates of total expenditure on energy consumption. This is logical, as households purchase energy products individually. Households can therefore say with certainty that a one litre bottle of kerosene is bought once a week for lighting, costing FJ$1.80. The same is not true of overall spending on energy.

[129] In the case of household expenditure on energy in 2004, only 44 households were able to provide an answer.

[130] Until 2010, the prices of many necessities were set on a monthly basis by the Prices and Incomes Board. Fuel prices were set in response to international oil prices and the value of the Fiji Dollar. The margins allowed wholesalers and retailers of these fuels were also specified. The legislation for price controls states that its purpose is to prevent inflation arising from increases in international prices. In recent years however, government statements when setting prices refer more to preventing monopoly pricing among retailers, especially in rural areas, than to attempts to control inflation. The newly created Commerce Commission (responsible for setting tariff rates for the FEA) took control of this function in 2010.

conducted in Fiji (Namoumou 2003). It was also evident in administering the survey. When asked about consumption of a particular form of energy, households would usually show a bottle or container that they used to collect each type of fuel, and could say with what frequency that fuel was purchased. This allowed for visual inspection of the amounts of fuel collected.

Table 5.5.1a compares data on present energy consumption calculated using this method to household estimates of total energy expenditure and the sum of household estimates of expenditure on individual fuels. The different sets of data are similar to one another, with the average sum of estimated expenditures on each form of energy being only a few dollars less than the average expenditure calculated using the method described above. For present expenditure, this method therefore seems to generate sound data.

Table 5.5.1a. Estimates of Monthly Household Expenditure on Energy using Different Methods

Method	Estimate of Average Expenditure ($FJ)
Total expenditure as estimated by respondents	42.33
Sum of expenditures on all forms of energy estimated by respondents	46.04
Expenditure calculated on the basis of energy consumption	47.32

The main advantage in using the method outlined above is that it can generate data on past energy expenditure for all households surveyed. This allows for a comparison of household expenditure in the present and the past among all households included in the survey.[131] The data generated from estimates of energy consumption are also considered more reliable than estimates of expenditure on energy, as highlighted above.

There are two disadvantages in using the method. One issue is that historical data on the price of candles and batteries were not available from the Prices and Incomes Board. Current prices are therefore used. The impact of this is considered to be negligible, owing

[131] Prices and Incomes Board data on prices in previous years are used, adjusting for mark-ups and transport costs observed in the surveyed communities.

to the minimal variations in price and the small amount spent on these items. A more significant disadvantage in using this method is that it does not account for substitution or changing consumption patterns. This is potentially a problem: discussions with communities suggested there had been some substitution when oil prices were high. However, the actual impact of this on the economic analysis does not appear to be substantial.[132] In response, data from household estimates of energy expenditure (using only the small survey sample) will be used as part of a sensitivity analysis.

Past and Present Spending on Energy: The Impact of High Fuel Prices

This section presents and compares average total monthly household expenditure on energy for the surveyed communities in three time periods: 2004, 2008 and 2009. Data are calculated using the method outlined above.

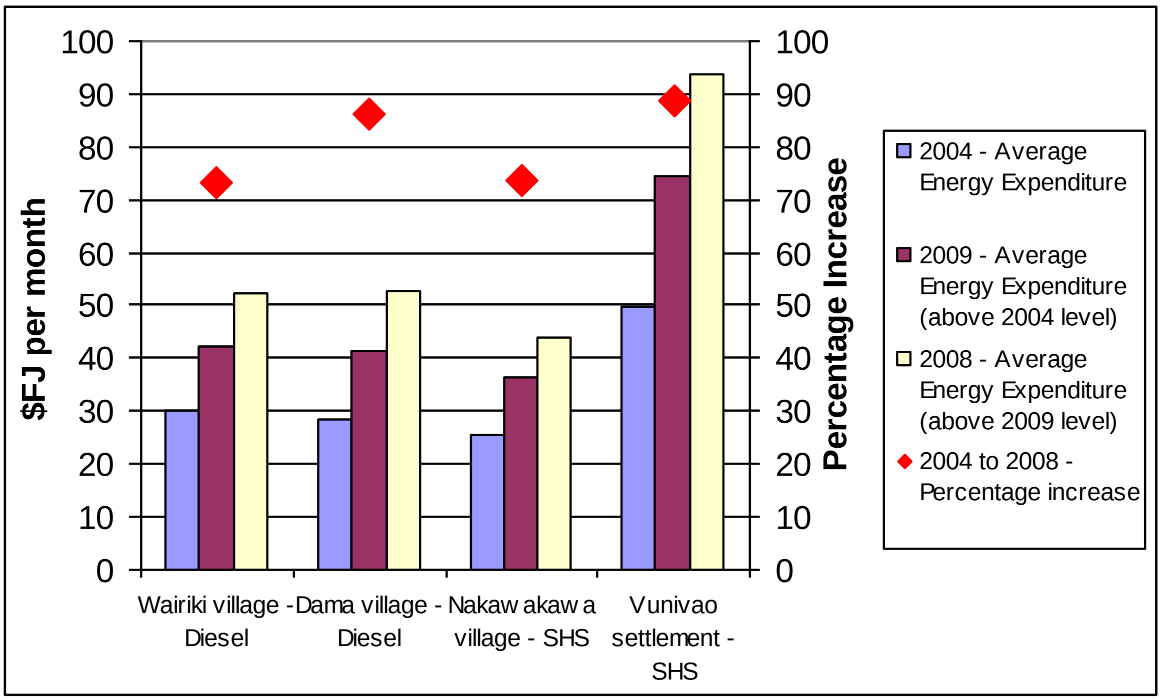
Average household energy expenditure for the four surveyed communities can be seen in figure 5.5.1a. Expenditure is lowest in 2004 (before fuel prices rose above their levels in the previous decade), is highest in 2008 (when fuel prices peaked), and lies between the two figures in 2009. The diamonds in the graph illustrate the percentage increase in household expenditure on energy between 2004 and 2008. What is most striking in the figure is the significant expenditure on energy among households in the Indo-Fijian community. This reflects the stronger links to the cash economy among Indo-Fijian cash crop farmers than among the indigenous Fijian villages studied here, and may also reflect the greater value placed on some of the services provided by electricity, such as lighting that facilitates school homework.[133]

Another interesting feature of the figure is that high fuel prices affected Vunivao settlement and Dama village to a greater extent (in percentage terms) than the other two Fijian villages. In part, this may be explained by the fact that most of the un-electrified

[132] As calculations from Prices and Incomes Board prices do not take into account the substitution effect, it was expected that the expenditure data generated from historical prices for 2008 (when fuel prices reached their peak) would be higher than actual expenditure in that year. For 2004, when fuel prices were lower, the opposite was expected (as those estimates are based on a cheaper basket of goods than was actually consumed by households in 2004). Neither of these expected results appears in the data.
[133] Education appeared to be a higher priority among Indo-Fijian households interviewed as part of this research than among indigenous Fijian households.

households surveyed were in these two communities.[134] Un-electrified households are shown below to be more vulnerable to increases in the price of fuels, as they spend more money on lighting fuels such as kerosene and benzine. The price of these fuels increased more significantly than the price of other fuels. The percentage increase in the price of different fuels between 2004 and 2008 is shown in table 5.5.1b.

Figure 5.5.1a. Impact of Fuel Prices on Household Expenditure on Energy among Surveyed Communities (based on calculations of energy expenditure based on household estimates of energy consumption and Prices and Incomes Board data)



[134] In Vunivao, half of all SHS had failed at the time of the survey, leaving households without electricity (and un-electrified for the purposes of this study). In Dama, there were also some households without access to electricity that had been built after the generator was installed in the early 1990s and had never been connected.

Table 5.5.1b. Fuel Price Increases, 2004 to 2008

Fuel Type	Percentage Increase in Price (2004-08)
Premix fuel*	44
Gas (LPG)	46
Unleaded fuel	57
Kerosene	125
Benzine	92
Diesel fuel	123

* Premix fuel is engine oil mixed with unleaded gasoline, typically used in small 2-cycle motors such as lawn mowers and small off board boat engines.
Source: Prices and Incomes Board, various documents

Also significant is the extent of household expenditure on energy relative to household income. Household expenditure on energy in 2008 is approximately one-quarter of total household cash income in the three indigenous Fijian villages, and at least 19.5 per cent of household income among Indo-Fijian households, based on household income presented in section 5.4.1. This is very high.[135]

High fuel prices resulted in substitution of cheap sources of energy for expensive energy sources, as well as reduced energy consumption. Survey data on this were not collected, but it was clear from interviews that households substituted wood for gas and kerosene for cooking, and in some cases substituted kerosene for benzine for lighting (kerosene lamps in Bua province are generally a lower quality and cheaper source of lighting than benzine lamps). The hours of lighting enjoyed by households also declined (Interviews in surveyed communities, November and December 2009). These impacts are important, as high fuel prices can be understood as forcing households to climb down the "energy ladder" by substituting cheaper and inferior sources of energy for more costly but superior energy sources (UNDP 2007b).

[135] For purposes of comparison, median household expenditure on energy in Australia in 2010-11 was estimated by Australian Treasury to be 6.5 per cent of household disposable income. Median household expenditure on stationary energy (electricity) was estimated to be only 2.4 per cent of household disposable income (Australian Government 2008).

The impact of high energy prices was nevertheless not as severe as the impact of high fuel prices for rural households, with household expenditure on food significantly higher than expenditure on fuel. This is discussed in Appendix A5.7.

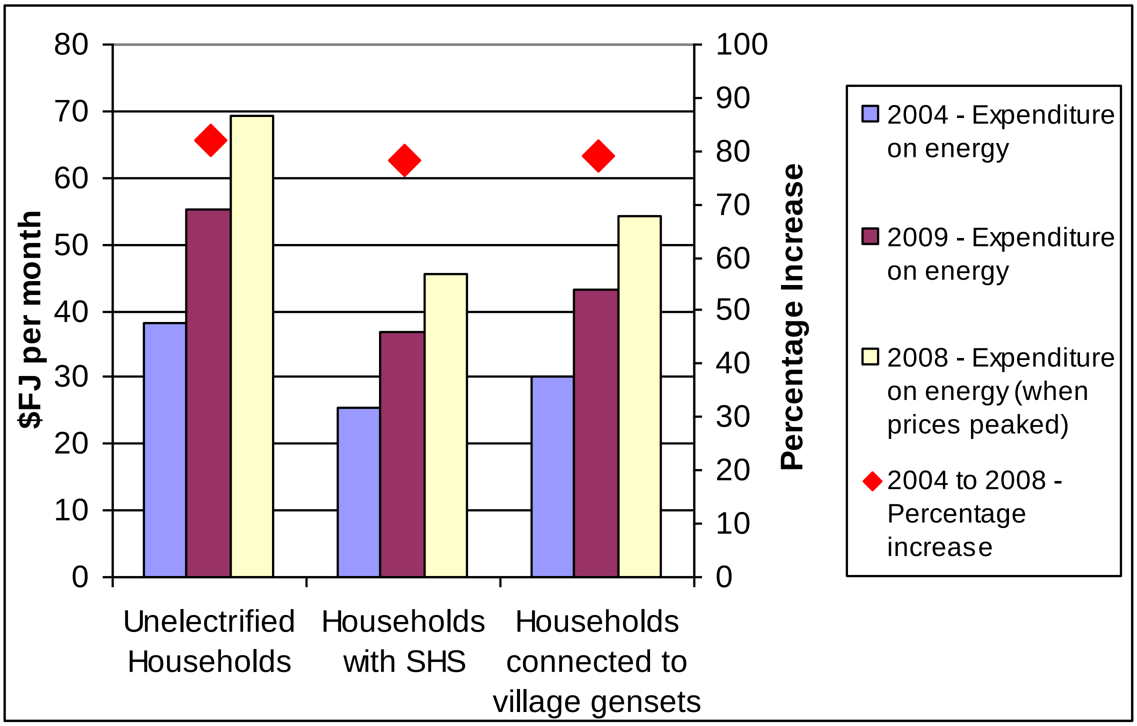
As part of a sensitivity analysis, the data presented in figure 5.5.1a was also compared to household estimates of expenditure on energy in different years (see Appendix A5.8). The key findings already discussed are confirmed by this comparison. Both sets of data show that:

- Energy expenditure was higher in Vunivao than in the other surveyed communities;
- Vunivao and Dama were more affected by increases in fuel prices than were Wairiki and Nakawakawa (which may be partly explained by the higher number of un-electrified households in those communities);
- Households in indigenous Fijian villages paid an average of approximately 70 to 90 per cent more on energy in 2008 as a result of higher fuel prices. This was a significant component of total household income.

The data on energy consumption gathered in this fieldwork, although more detailed, are also consistent with data gathered in previous surveys (an overview of those surveys is provided in Appendix A5.1). This is described in Appendix A5.9.

The same data on the impact of high fuel prices on rural households are presented in figure 5.5.1b, distinguishing between households that are un-electrified, have SHS installed, or are connected to a village generator. The figure shows that un-electrified households spent the most on energy products. This reflects the fact that the use of kerosene, benzine and batteries for lighting is more expensive than the use of electricity, a finding that has been confirmed by many studies of rural electrification in developing countries and is to be expected (Barnes and Floor 1996; ESCAP 2005; REN21 Renewable Energy Policy Network 2005; UNDP 2007a). Un-electrified households were also marginally more affected in percentage terms by the increase in fuel prices (as shown by the diamonds in figure 5.5.1b). This was due to the price of kerosene increasing more than the price of other energy products.

Figure 5.5.1b. Impact of Fuel Prices on Expenditure on Energy among Households with Different Electrification Technologies



The expenditure of businesses is included in figure 5.5.1c (it is excluded in the previous figures). Businesses that were surveyed included two carrier drivers, a general store owner and the operator/owner of a rice mill.[136] All were owned and operated by Indo-Fijians. The data shows that although total energy related expenditure for businesses is far greater than for households, the impact of high fuel prices on businesses in percentage terms was marginally lower than for households. This can be explained by the fact that businesses spend less on kerosene and more on unleaded and premix fuel as a proportion of their total spending than households.

[136] Although a small sample, these businesses comprise a large portion of the limited number of businesses in the surveyed communities.

Figure 5.5.1c. Impact of Fuel Prices on Expenditure on Energy among Households and Businesses

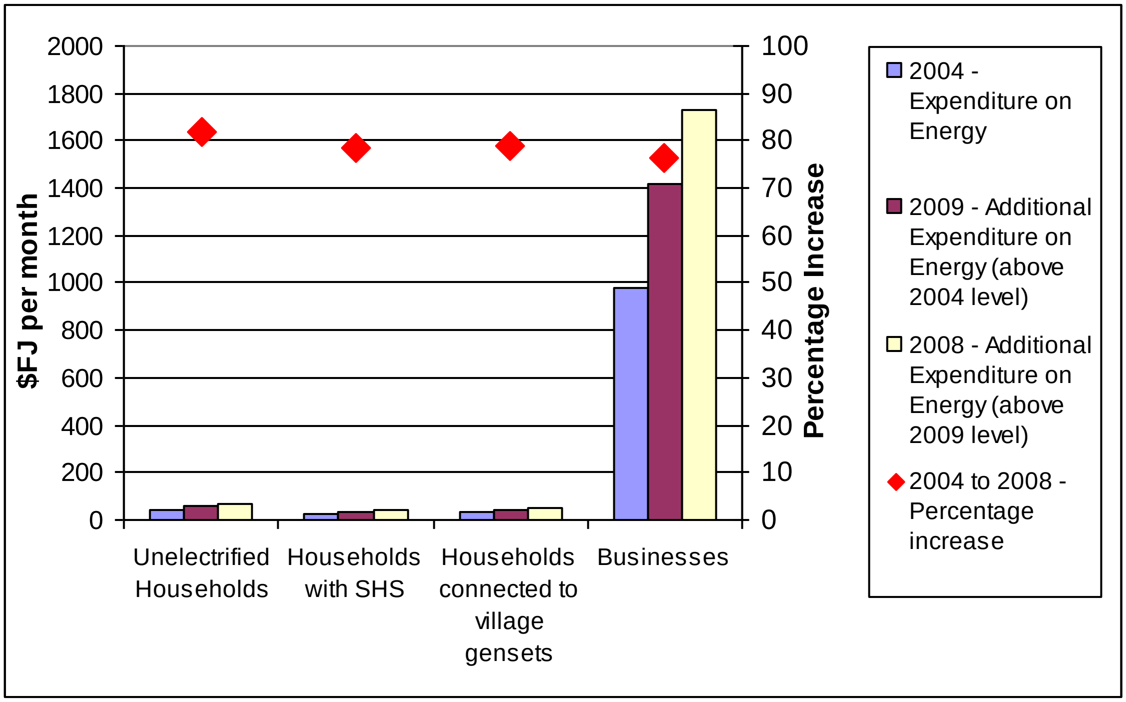
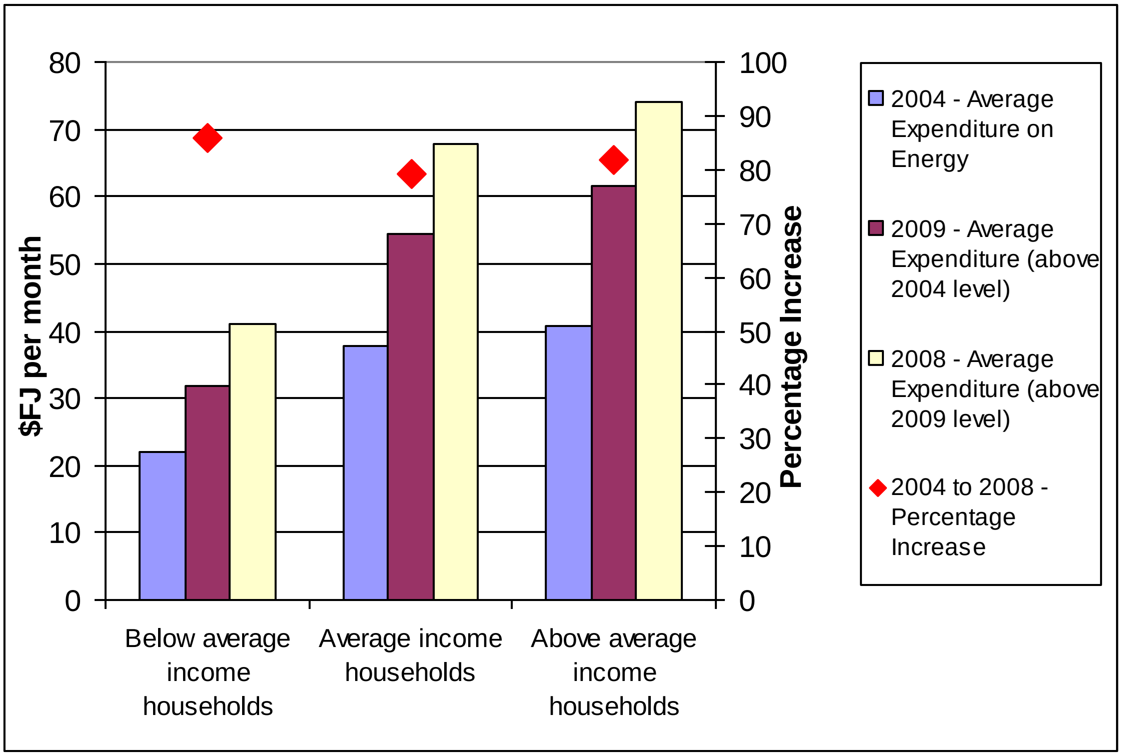


Figure 5.5.1d offers a different perspective. It separates the data on energy expenditure on the basis of household income, or more specifically, whether households appear as below average, average or above average income households. As would be expected, above average income households spent the most on energy in absolute terms, while below average income households spent the least. The impact of high fuel prices in percentage terms however was felt marginally more by below average income households, followed by above average income households.

Again, the reason for this is the price increases of different fuels. Below average income households spent more on kerosene and benzine as a proportion of total spending on energy than average and above average income households. For above average income households, more was spent proportionally on gas for cooking and on diesel fuel for the operation of individual generators. It should also be noted that below average income households are likely to spend more on energy as a percentage of total income than above average income households.

Figure 5.5.1d. Impact of Fuel Prices on Expenditure on Energy among Households of Different Income Levels



The Composition of Energy Expenditure

Differences in the impact of high fuel prices are the result of the composition of energy consumption of households. For cooking, households used wood, gas and to a lesser extent kerosene. Wood was the most commonly used fuel, and was free for most households (some Indo-Fijian households paid a very small fee twice a year to gather wood from land owned by indigenous Fijians). Gas was used mainly by above average income households, which were willing to pay for the ease of using gas instead of wood for cooking. For lighting, households commonly used electricity, kerosene and benzine; and to a lesser extent used petrol (for operating small generators), batteries and candles. Two varieties of petrol (unleaded and premix) and diesel fuel were used for a range of purposes, including powering small generators, boats, brush-cutter lawn mowers, and chainsaws.

Figure 5.5.1e shows composition of expenditure on energy among businesses, un-electrified households, households with a SHS installed, and households connected to a village diesel generator. The composition of expenditure varies considerably between groups. Among households without access to electricity, spending is highest on lighting fuels such as benzine and kerosene, and on batteries and candles. Expenditure on gas is also high for these households, reflecting the fact that many un-electrified households surveyed were located in the Indo-Fijian community of Vunivao, where wood was scarcest (and sometimes had to be purchased) and where households are more integrated into the cash economy.

A FJ$14 monthly fee for electricity forms the largest component of spending on energy for households connected to SHS under the *RESCO Program*. These households spend approximately FJ$19 less on lighting (kerosene and benzine fuels, as well as candles and batteries) than do un-electrified households, indicating that the use of a SHS for lighting is cheaper than using traditional fuels. This is confirmed by the opinions of households, provided in section 5.5.2. The difference was not so great for households connected to village diesel generators. Households in these communities only have access to electricity for approximately 3 hours per day, meaning that they must also consume traditional lighting fuels such as kerosene, although not to the same extent as un-electrified households.

The data show that businesses in Vunivao spend considerable amounts on petrol and diesel, which is used to operate carrier vans, the rice mill processer, and a generator that provides electricity for refrigeration of meat and other goods sold in the shop. Business owners could afford to use gas for cooking as part of household energy consumption.

Figure 5.5.1e. Composition of Energy Expenditure among Households and Businesses (as a proportion of total energy expenditure)

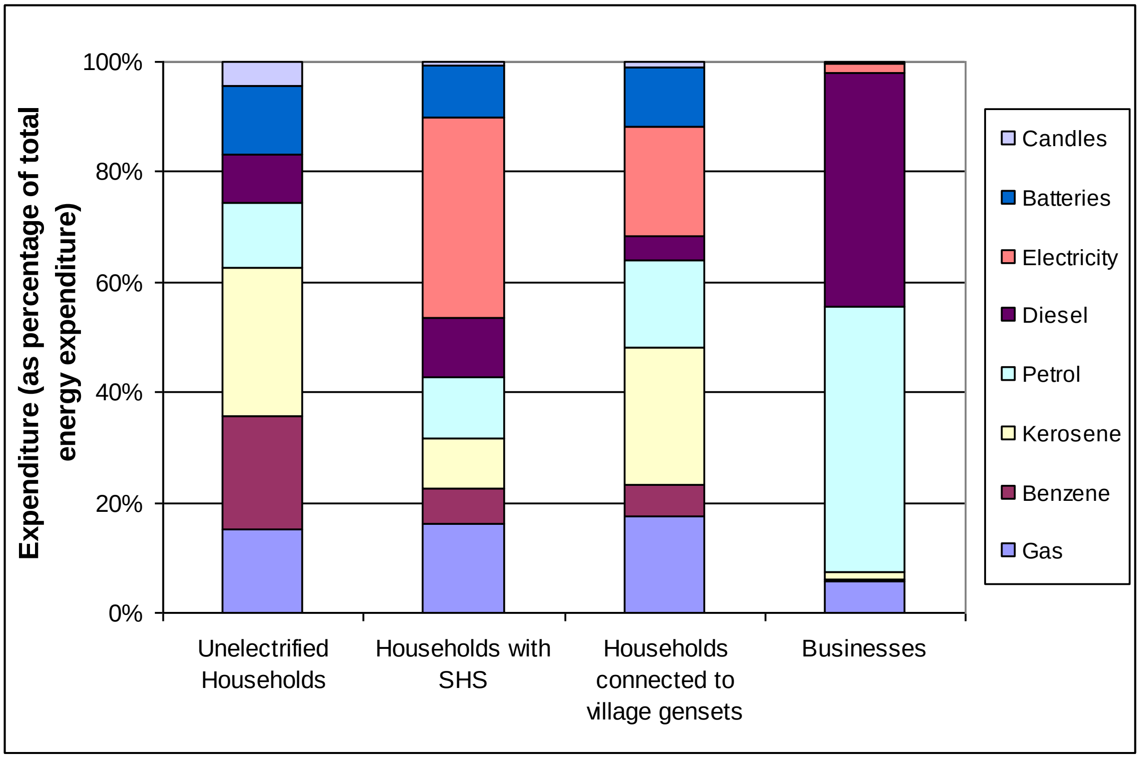
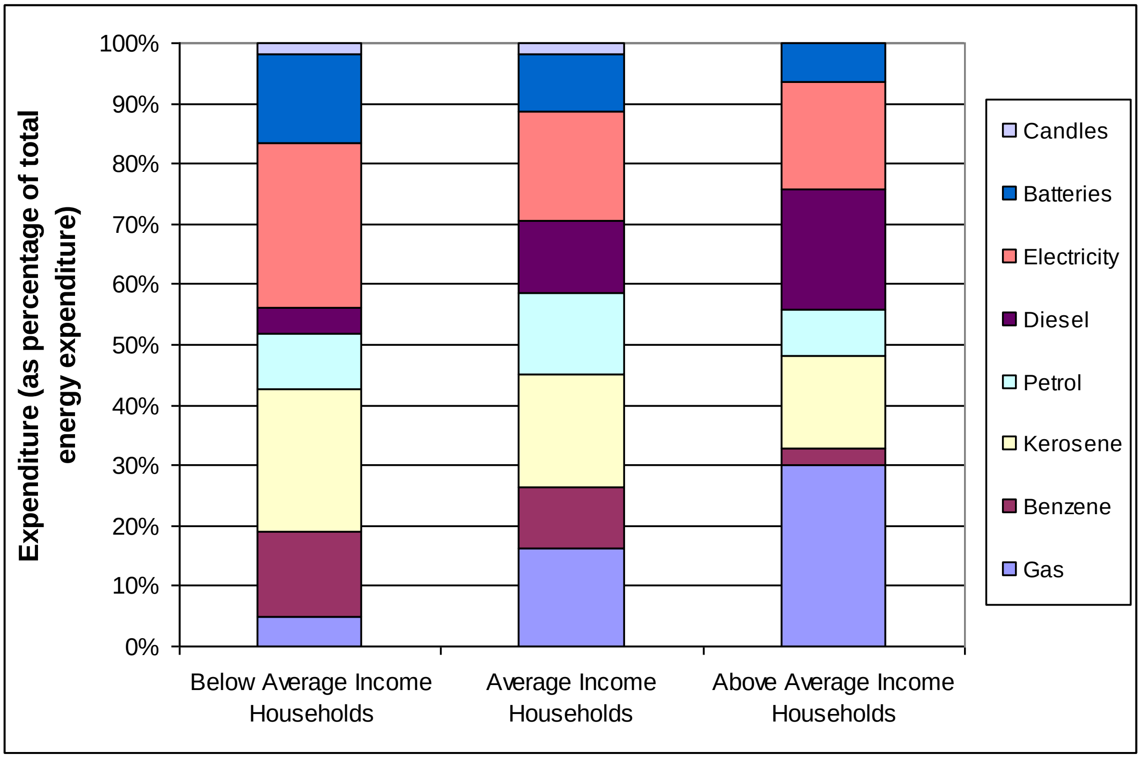


Figure 5.5.1f separates expenditure among households with different estimated income levels. The data confirm the findings of the previous section, and demonstrate that:

- Households with higher incomes spend more in absolute terms on energy than those with lower incomes;
- Below average income households spend more on kerosene and benzine as a proportion of total spending on energy than other groups; and
- Above average income households spend more on gas and diesel fuel for household generators than other groups.

The different price movements of these fuels explain the marginally larger impact of high fuel prices on below average income households and above average income households. These groups were affected by the large increase of the price of kerosene and benzine (for below average income households) and diesel fuel (for above average income households). Average income households spent less on these fuels as a proportion of total energy related spending.

Figure 5.5.1f. Composition of Energy Expenditure among Households with Different Income Levels (as a proportion of total energy expenditure)



The survey results point to a number of conclusions.

- Fuel price volatility has a significant impact on rural households, with energy expenditure consuming up to 25 per cent of household income when prices are high;
- Un-electrified households are most affected by fuel price volatility, as a result of their reliance on kerosene and benzine fuels for lighting;
- Electrification is of financial benefit to rural households. Expenditure on energy in the surveyed communities was lower among electrified households than un-electrified households. Installation of SHS appears to be of greatest financial benefit.

5.5.2 Electricity Supply and Consumption Data

Electricity in Off-grid Areas: Use and Access

Access to electricity

Households in Fiji have a choice about what electrification technology they adopt under rural electrification policies. Respondents were asked about the reason they chose diesel or solar technology in the survey questionnaire. Responses are shown in table 5.5.2a.

Table 5.5.2a. Reasons for Choosing Diesel or Solar-Based Electrification Technologies (number of responses)

	Diesel Generator		Solar Home Systems	
	Wairiki village	Dama village	Nakawakawa village	Vunivao settlement
Decided by head of village	11	14	2	0
Recommended by DoE	0	1	11	2
It was cheaper	4	13	6	15
It does not depend on good weather to work	15	9	0	0
I do not pay for the power of other households	7	2	9	0
It is more reliable	1	11	1	0
It is better for the home environment	6	8	13	13
Its cost is always the same	0	2	17	0
I can use power whenever I want	0	0	2	5
It does not need fuel, which runs out	0	0	4	12

The three most common responses for choosing diesel-based generation included (in order of responses):

1. Decided by head of village (25 responses)
2. It does not depend on good weather to work (24 responses)
3. It was cheaper (17 responses)

Many households in these communities also said that it is better for the home environment, and it is more reliable.

The most common reasons for choosing solar technology in Vunivao and Nakawakawa included (in order of responses):

1. It is better for the home environment (26 responses)
2. It was cheaper (21 responses)
3. Its cost is always the same (17 responses, all of them in Nakawakawa)
4. It does not need fuel, which runs out (16 responses)

In Nakawakawa, "It was recommended by the Department of Energy" was also a common response (13 responses, 11 of them in Nakawakawa), as was "I do not pay for the power of other households" (9 responses) (which refers to the non-excludable nature of power from village-based diesel systems, explained below and analysed in chapter six). Not reflected in these survey results were the large number of households that stated in interviews that the advantage of having a SHS was that they could access power (or light) at any time of the night.

Cost was an important issue for all households. Households in Wairiki and Dama said that diesel-based generation was cheaper, because at the time their systems were installed the upfront cost of a diesel system was considerably cheaper than that of a SHS. In Vunivao and Nakawakawa on the other hand, the SHS installed under the *RESCO Program* had a considerably lower cost than did a diesel system installed under the *Rural Electrification Policy*. References by households in Wairiki and Dama to SHS not working in poor weather indicate a lack of knowledge about the SHS installed under the *RESCO Program* (the power generated by SHS is reduced in poor weather, but should still be satisfactory given normal use). This lack of knowledge was also shown in general discussion, where for example many villagers believed that SHS could power appliances.

The hours in which electricity was available varied. In Wairiki and Dama, the diesel generator was operated for 3 hours each night, between 6pm and 9pm. In the past when fuel prices were low, the generators were operated for 4 hours each night, from 6pm to 10pm (Department of Energy 2006b). In the communities with SHS, electricity was available at any time, unless the system was overused. Most households claimed that the system could power one light all night, while most households actually used several lights for between 3 and 6 hours. Households also said that in the wet season less power was available, with some households claiming their SHS could only power lights for 2 hours each night during periods where it rained constantly over several weeks. When this occurred, SHS would commonly be operated until the battery could no longer provide adequate power (at which point the SHS would switch off) (Interviews in Vunivao and Nakawakawa, December 2009). This was a more common problem for households in Nakawakawa, which has a significantly wetter climate than Vunivao.

Use of electricity

Households used electricity for lighting and to power appliances. In Vunivao and Nakawakawa, electrical appliances (excluding radios) were only used with small household generators, given the inability of SHS to power appliances. In Wairiki and Dama on the other hand, households would use all their appliances during the 3 hours in which electricity was available.

There was very little use of electricity for income generation in the areas surveyed. This is consistent with previous surveys of the area.[137] Only four of the 78 households surveyed used electricity to generate income. Two of these were in Vunivao, including a shop that used a generator to power freezers and a rice mill that also operated with a generator. In Nakawakawa, one above average income household received FJ$1 each time someone in the village charged their mobile phone using their generator. In Wairiki, one household owned a freezer that it used to keep fish that were purchased from other households in the village and were sold in the market once a week. The freezer was powered using the village

[137] The Department of Energy's *Rural Electrification Survey* found that in 2005, none of the households surveyed as part of this research project generated income from electricity.

diesel generator and, when the village generator was not available, a household portable generator. No household used SHS to generate income. These results cast doubt on arguments for rural electrification that refer to income generation as a benefit of electrification.

The use of electricity in extending the hours that children can study on the other hand was confirmed by the fieldwork. Although the survey did not ask households about their use of lighting, many respondents, when asked to provide additional comments, spoke about how lighting facilitated the education of their children. Discussions with households indicated that this was clearly the most important use of electricity for the majority of households surveyed (Interviews in Bua province, November and December 2009).

Household lighting and ownership of electrical appliances were also explored by the survey (details are provided in Appendix A5.10 and A5.11). Households with SHS were found to have more lights than households connected to a diesel generator. This reflects the practice of the Department of Energy, which in the *RESCO Program* normally installs four or five lights in each household, whereas for a diesel scheme the installation of two or three lights is the norm (Interviews with Department of Energy staff, November 2009). In Vunivao, many households with average and above average incomes had two sets of lighting systems installed: one operating with the SHS, and the other operating with a portable petrol generator owned by the household. This provided these households with additional security of supply and also served to reduce use of the SHS battery.

Appliance ownership among surveyed households is shown in table 5.5.2b. The most common appliance was a radio, which was owned by 56 of the households surveyed. Television and video or DVD sets (there is no television reception in Bua province so video or DVD sets are required for a television) were the second most common appliance found in households. Other appliances owned in some households included mobile phones (11 households), fridges or freezers (freezers were more common given electricity is not available all day), washing machines and irons.

Appliance ownership has increased considerably since 2005 in Wairiki, Dama and Vunivao, as shown by data from the *Rural Electrification Survey*.[138] The increase emphasises the demand for appliances among households. A majority of households also sought to purchase power-hungry appliances found in urban areas, when asked what appliances they would purchase if the funds and power were available. Detailed survey results are provided in Appendix A5.11.

Table 5.5.2b. Appliance Ownership in Surveyed Communities

	Wairiki	Dama	Nakawakawa	Vunivao	Total
Radio	14	9	19	14	56
Television and video/DVD	11	9	14	13	47
Mobile phone	4	2	5	0	11
Fridge or freezer	1	2	0	3	6
Fan	2	0	0	1	3
Washing machine	1	4	1	0	6
Iron	0	4	0	4	8
Blender	0	2	0	1	3
Rice cooker	0	1	1	2	4
Other	0	0	1	2	3

The results presented in this sub-section show that use of electricity varies across households and communities. The data suggest that rural households in Fiji are unlikely to use electricity for income generation, and that instead, the value of electricity in the short to medium run is the result of savings on energy expenditure (discussed in section 5.5.1), and improvements in quality of life. In the long run electricity is a pre-requisite to economic development. Households clearly value the lighting provided by electricity, with many households mentioning how it extends the hours that their children are able to do homework, and some households also stating that it allows the family to socialise at night.

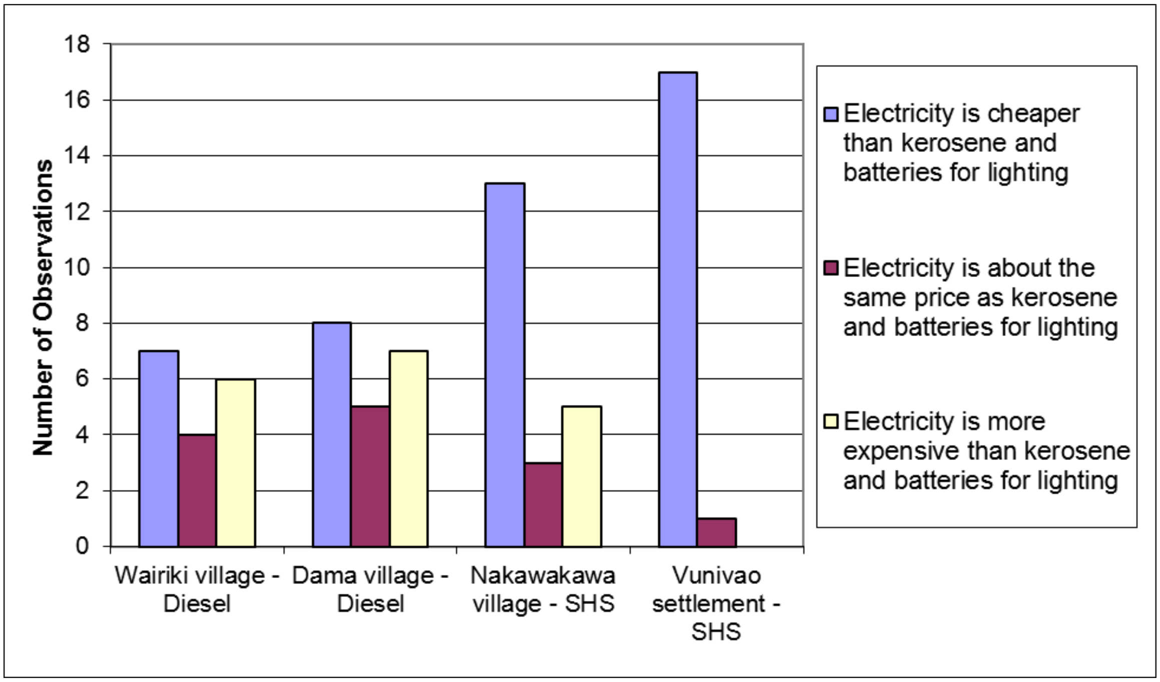
[138] Ownership of television and video sets has more than doubled. In many cases, appliances not present in the surveyed communities in 2005 are now owned by households, such as fridges and freezers, fans, blenders and rice cookers. In the case of mobile phones, this rapid growth can be explained by the installation of mobile phone towers providing reception to much of Bua province.

The survey also shows that rural households in Fiji aspire to own power-hungry appliances typically owned in wealthy urban households, such as washing machines and refrigerators (this is detailed in Appendix A5.11). Whether households can afford these appliances is another matter: current income levels suggest that only above average income households are likely to be able to purchase the appliances in the foreseeable future. This highlights the importance of offering different alternatives to households under rural electrification programs. Neither the one size fits all approach of the *RESCO Program*, nor mini-grid diesel generators, are satisfactory in this regard.

Spending on Electricity

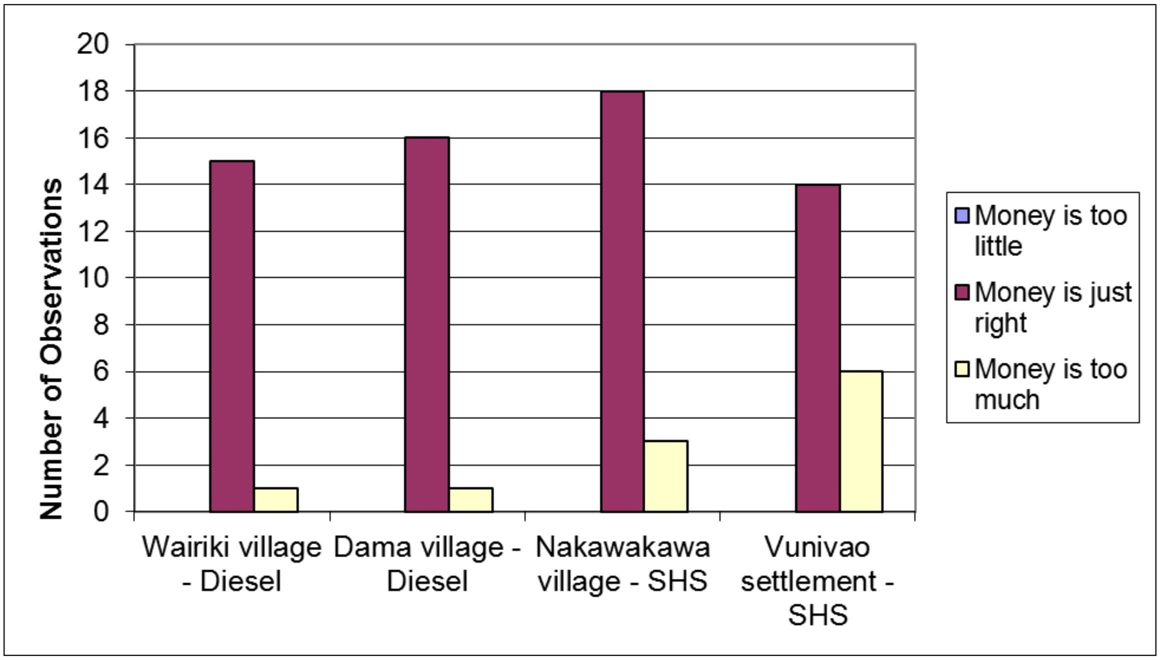
Households were asked to compare the cost of electricity to the use of kerosene and batteries for lighting; the most common forms of lighting for un-electrified households. Responses are shown in figure 5.5.2a. Most respondents were of the opinion that electricity provides a cheaper form of lighting, however this response was far more common in the two communities where SHS are installed. This is not surprising, given that SHS provide lighting at any time whereas diesel generators only provide lighting for 3 hours per day. The higher number of answers in favour of electricity in Vunivao compared to Nakawakawa may be due to Indo-Fijian households spending more on lighting fuels than is normally the case among indigenous Fijian households.

Figure 5.5.2a. Perceived Cost of Electricity among Rural Households



Households were also asked whether the money they paid for electricity was "too much", "too little" or "just right". This question was included in order to gauge willingness to pay for electricity among surveyed households (see figure 5.5.2b). The majority of households in all communities believed payments for electricity were just right, while a small number thought payments were too high. Discontent with the amount paid for electricity was highest in Vunivao, and is probably the result of poor SHS performance (discussed later in this section).

Figure 5.5.2b. Perceptions on Collection of Money for Electricity



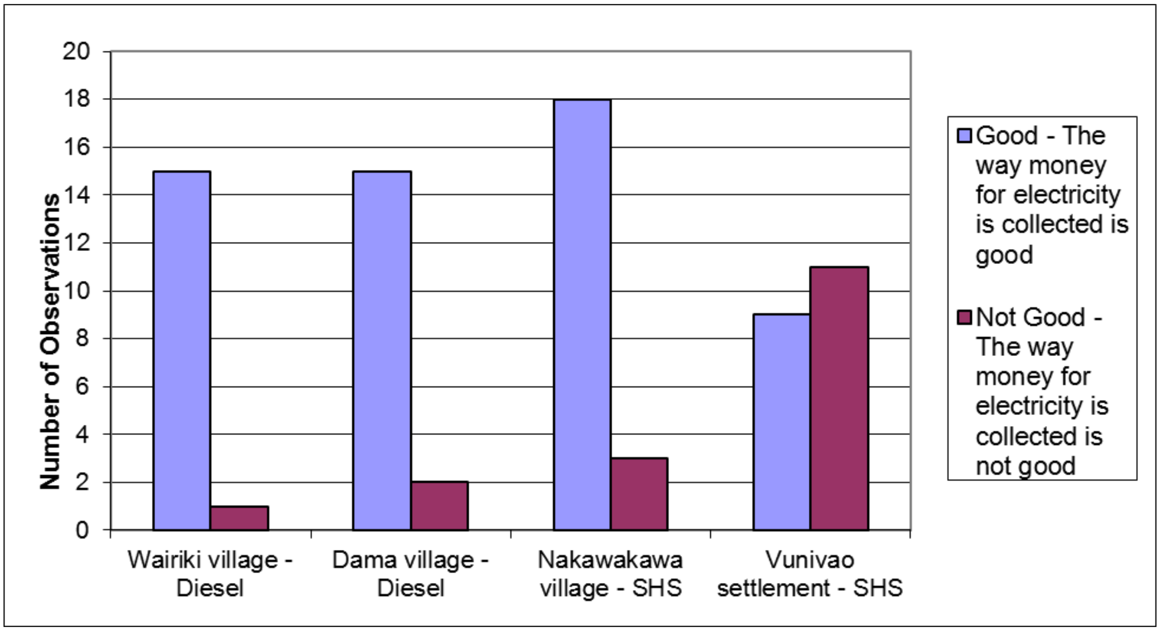
In other questions, respondents were asked about the amounts they spend on electricity and the way that money is collected. Spending on electricity varied. Households with a SHS are required to pay a FJ$14 fee each month. In Dama and Wairiki, household expenditure on fuel for the generator was around FJ$10 per month, and was paid through a *soli* (the means of collection are detailed in chapter six).

Households in both communities were also asked about past payment for electricity. Unfortunately, answers varied enormously and are therefore not reliable. Survey results from Dama and Wairiki in the 2005 *Rural Electrification Survey* are better, and show that households in Dama paid FJ$10 once a month at the time; a similar amount to what is paid now. In Wairiki, households paid FJ$2 per week for electricity (so a little more than FJ$8 per month).[139] These amounts provided power for four hours each night (from 6pm to 10pm) in both communities, one hour more than when the survey was conducted.

[139] An interesting observation of payments for electricity is how regressive collection methods are towards poorer households. Low income households have fewer appliances and lights, but pay the same amount for electricity as wealthier households (although some exceptions are made, with some of the poorest households in both communities allowed to pay less).

Most households were satisfied with existing arrangements for collecting money for provision of power (see figure 5.5.2c). Vunivao was an exception, with a majority of households unsatisfied with the current payment system, which sees them having to purchase SHS codes/tokens from the Post Office in Nabouwalu. This is about 40 minutes by bus from Vunivao, and the fare costs several dollars in each direction. In Nakawakawa, households said that until recently a similar problem existed, with households having to travel several hours by bus to Nabouwalu to purchase the SHS code/token. This arrangement was improved in October 2009 (one month before the fieldwork), with codes/tokens now sold in nearby Daria instead.

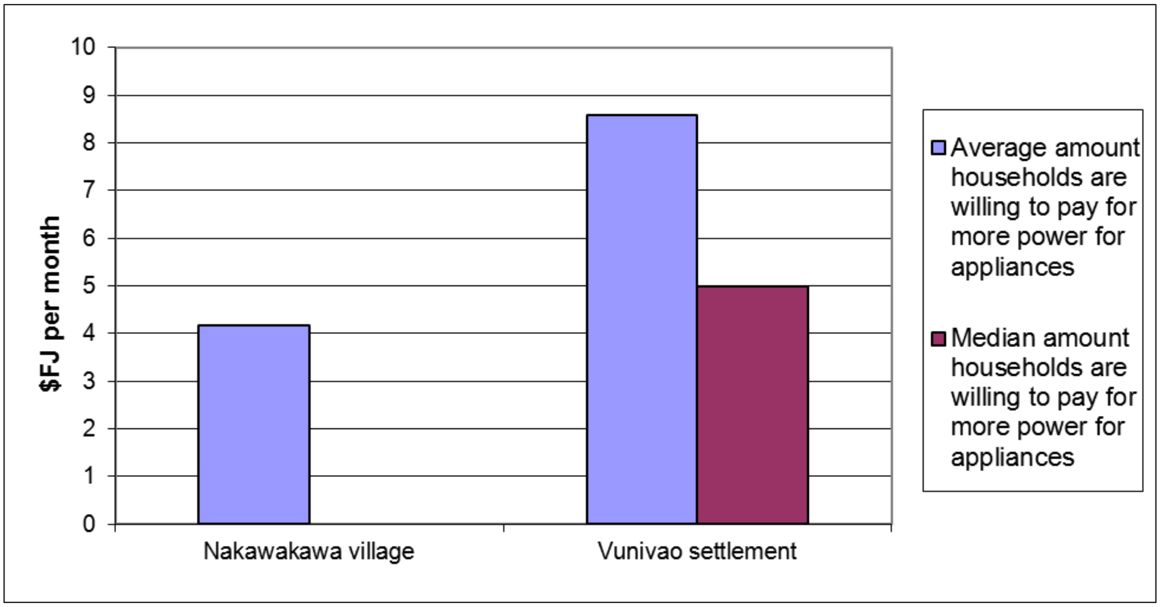
Figure 5.5.2c. Perceptions on the Collection Method for Money for Electricity



The survey also sought to assess willingness among rural households to pay more for electricity. In communities with SHS, the survey questionnaire asked respondents whether they were willing to pay more for SHS that could power appliances. In Nakawakawa a majority say they were not, whereas in Vunivao a majority said they were. The average and median amounts of extra money households were willing to pay each month for a SHS that could power appliances is shown in figure 5.5.2d. Although the average in Vunivao was high (at about FJ$8.90 per month), the median was just FJ$5, meaning those households would be willing to pay a total of FJ$19 per month for a SHS that could power appliances (given the existing fee of FJ$14). Among households that answered the 2005 *Rural*

Electrification Survey, the average extra amount they were willing to pay for a SHS that could power appliances was almost identical (up from FJ$8.76 to FJ$8.90 per month).

Figure 5.5.2d. Willingness of Households with SHS to Pay More for Power for Appliances



All households surveyed were of the opinion that a reliable electricity supply was "very important". Not all however were willing to pay for a reliable electricity supply (defined to households as a supply that never suffers unintended power outages). Figure 5.5.2e shows that in three communities, a majority of households were willing to pay for a more reliable power supply. Nakawakawa was the only community where more households said they would not pay more. This could relate to the lower cash incomes in Nakawakawa (given distance from markets), and is probably also a result of households in Nakawakawa suffering fewer power outages (measured in terms of days per year) in 2008-09 compared to other surveyed communities (this is detailed in the next sub-section). Figure 5.5.2f shows the additional amount that households in each community were willing to pay for a reliable electricity supply.[140]

[140] Strangely, among households that said they were willing to pay more for a reliable electricity supply, the amount households were willing to pay for a reliable electricity supply was highest in Nakawakawa (although it should be noted that this represents the responses of only five households).

Figure 5.5.2e. Willingness to Pay for Reliable Electricity Supply (Yes/No)

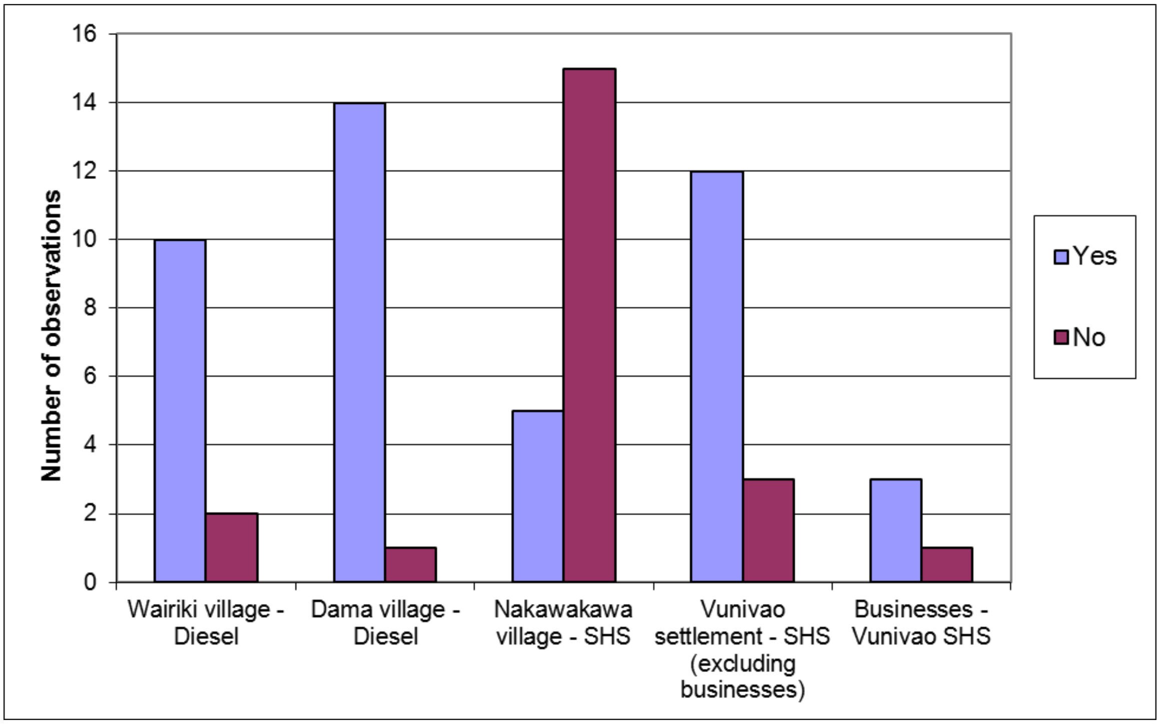
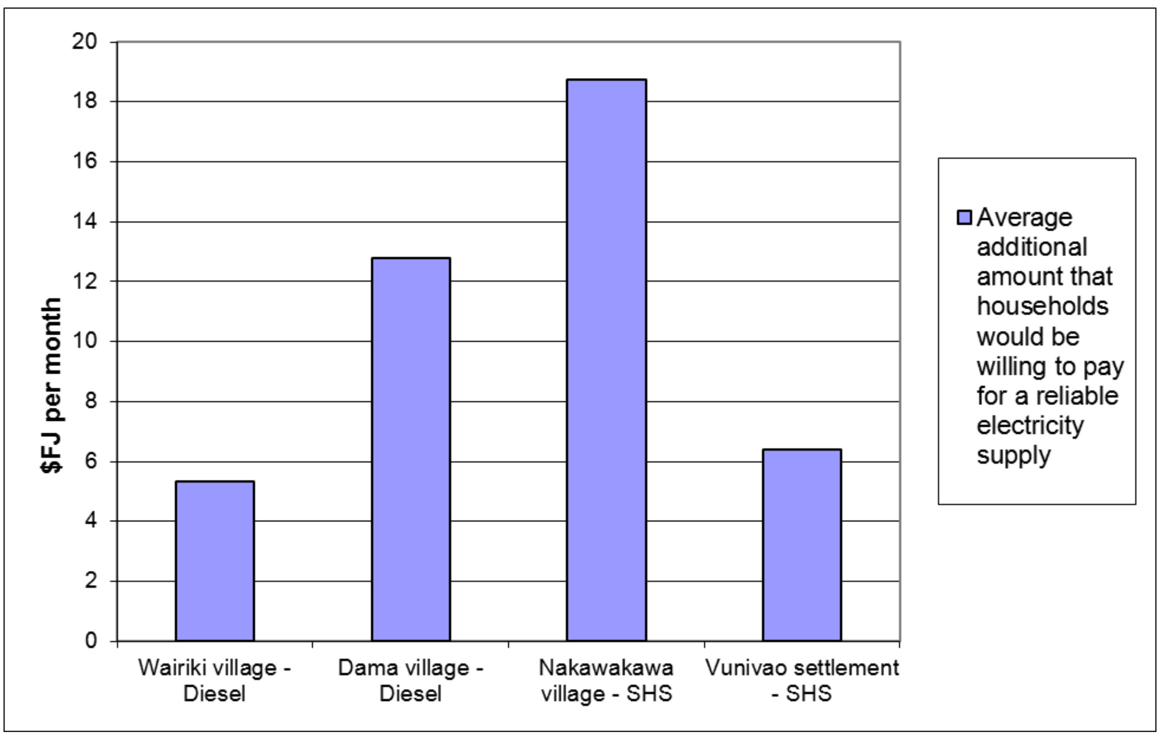


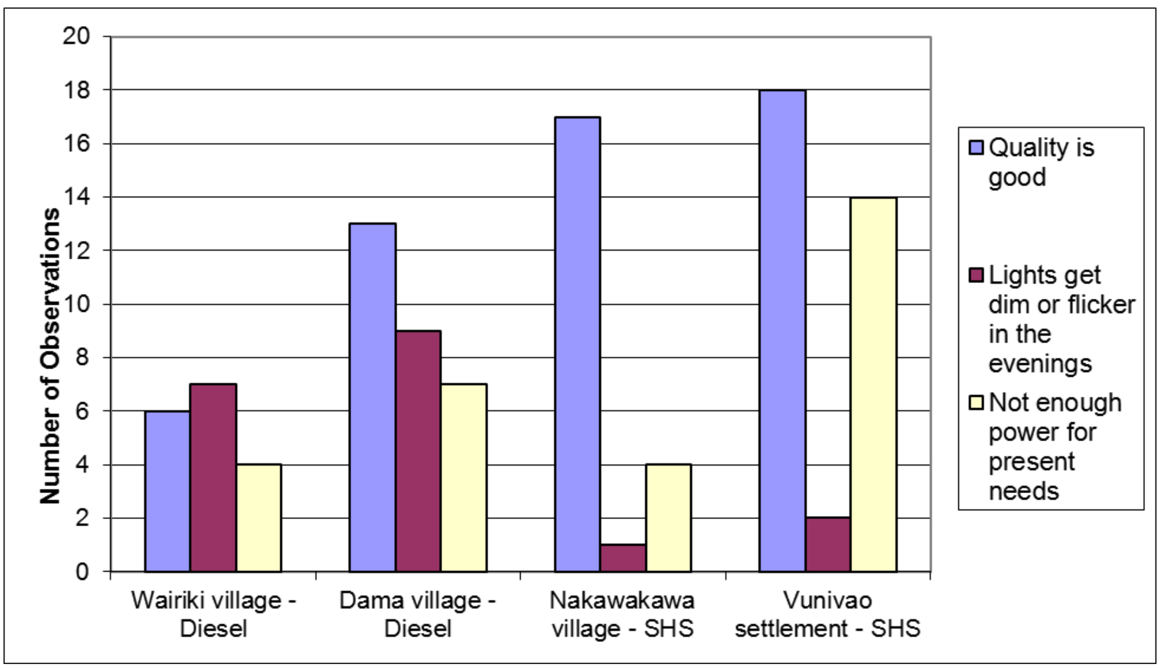
Figure 5.5.2f. Willingness to Pay for a Reliable Electricity Supply



Reliability and Quality of Electricity

Respondents were asked whether the quality of electricity supply was good, if lights were dimmed or flickered, and whether they had enough power for present needs.[141] They could answer "yes" to more than one of the questions. Results are shown in Figure 5.5.2g. Households generally considered the quality of electricity supply to be good. Some households in Wairiki and Dama complained that lights would flicker or become dim in the evening (many saying this also agreed that the supply of electricity was good). The operator of the generator said this was the result of the generator being overloaded with appliances. Both villages were looking into purchasing newer more powerful generators from the Department of Energy at the time of the survey. The same problem led some households in Dama and Wairiki to state that there was not enough power for present needs. In Vunivao, a majority of households stated more power was required; many arguing that the SHS should also power electrical appliances (while also saying that supply was good). Most households in Nakawakawa did not see this issue as important.

Figure 5.5.2g. Perceptions about the Quality of Electricity

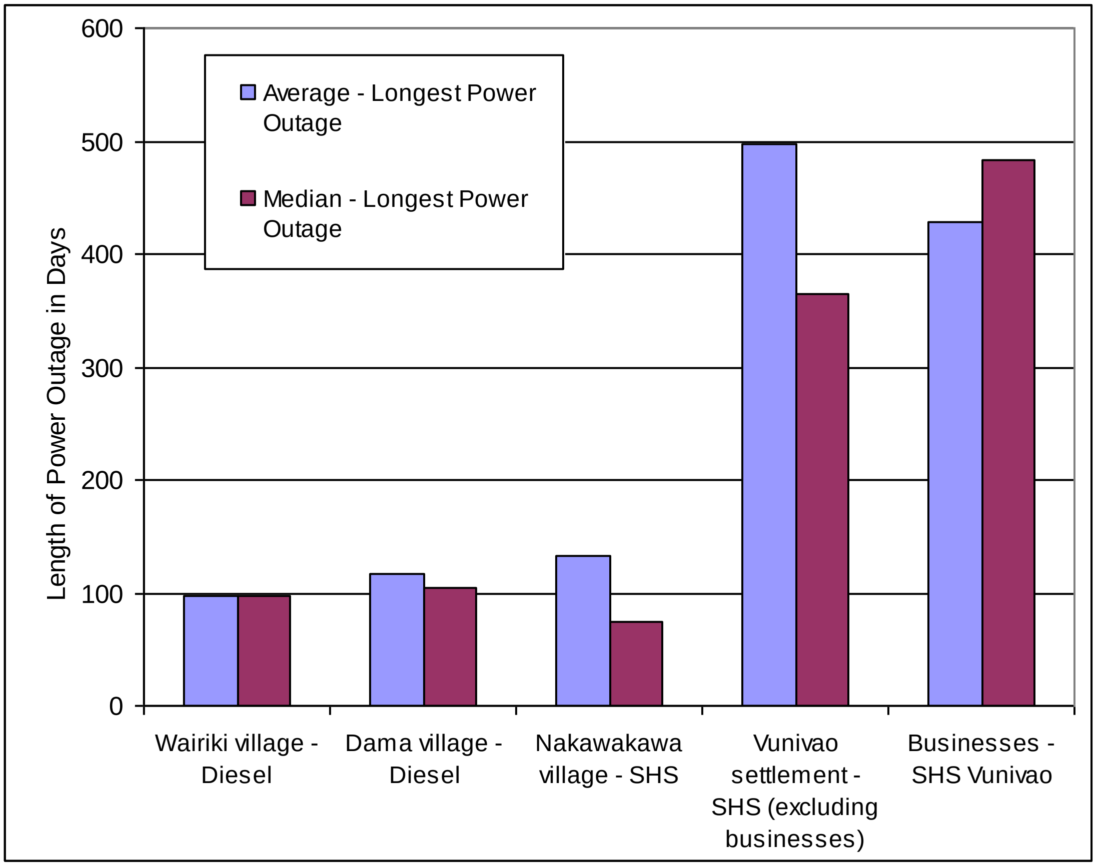


[141] This question was based on a question asked in the 2005 *Rural Electrification Survey* (Department of Energy 2006b).

The survey included questions on power outages and the reliability of electricity supply for each household. Respondents were asked about all power outages, including those resulting from technical problems or an inability to pay for fuel or fees. The average and median responses for each community are illustrated in figure 5.5.2h. The duration of power outages was high for all the communities surveyed. In Dama and Wairiki, the two villages with diesel generators, the duration of the longest power outages experienced were approximately 98 and 117 days.[142] In the two communities with SHS, the length of power outages varied between households. In Nakawakawa, the median was lower than in Dama and Wairiki but the average was higher (75 and 132 days respectively). The reason for this difference was that a few households whose systems had not worked for a long time significantly increased the average. Figures were highest in Vunivao, where the average duration of the longest power outage suffered by households was almost 500 days, while the median was over 300 days. Again, the discrepancy between the average and median is due to a number of households where SHS had not functioned for several years.[143]

[142] In Dama and Wairiki the average and median for each village should be equal as the generator supplies all households. Unfortunately in the case of Dama, the responses of various village committee members responsible for the generator's operation were not same.
[143] The discrepancy was reversed in the case of businesses in Vunivao, where one business that had suffered few problems with its SHS lowered the average.

Figure 5.5.2h. Duration of Longest Power Outage (in days)



	Wairiki village - Diesel	Dama village - Diesel	Nakawakawa village - SHS	Vunivao settlement - SHS (excluding businesses)	Businesses - SHS Vunivao
Average	98	117	133	497	429
Median	98	105	75	365	483

The same question about the duration of the longest power outage was also asked in 2005 in Vunivao as part of the *Rural Electrification Survey*.[144] Results for the survey sample used in 2009 are shown in table 5.5.2c. In the four years since 2005, the average length of the longest power outages reported by households in Vunivao has increased enormously. The reasons for this relate to the breakdown of the institutional systems put in place for maintenance (discussed in chapter six). Problems with the prepayment meter used in the SHS are also responsible.[145]

144 The question was not asked in Dama or Wairiki.

145 SHS installed before 2005 included a "conlog" prepayment meter (used to ensure households paid the monthly fee), which was produced by a South African company. In 2005, that company ceased production, leading to a shortage of parts that could be used to repair broken prepayment meters (Interviews with Department of Energy and RESCO, November and December 2009). All prepayment meters consequently had to be replaced with "enercash" prepayment meters. The survey discussions suggest that in many cases these meters were not installed correctly by the contractor, leading SHS in many households to cease functioning.

Table 5.5.2c. Average Duration of Longest Power Outage in Vunivao, 2009 and 2005 (from same survey sample)

	2005	2009
Average number of days	8.6	458

The previous two figures do not examine the reasons for power outages. Information on the causes of power outages was gathered in another survey question, which asked respondents about power outages in 2009 and 2008. Households were asked the cumulative length of power outages in each year that had resulted from:

- Technical problems
- Affordability issues:
  - A household not having enough money to pay the fee for a SHS, or
  - A village not raising enough money to purchase fuel for the generator
- Logistics – weather or transport issues preventing:
  - Payment of the SHS fee, or
  - Purchasing of fuel for a diesel generator.

This question captured both long-term and short-term power outages. For households with SHS, answers were checked against the records of the RESCO and log books kept in each household as part of the *RESCO Program*, and the few significant inconsistencies removed from the data presented here.

Results are shown in figure 5.5.2i and table 5.5.2d. For SHS, technical problems were the greatest problem: households with SHS on average suffered 87 days of power outages resulting from technical problems in 2008, and 146 days in 2009. As with the previous figures, these averages are higher than the median, as a result of households with SHS that did not function throughout either year. The median figures for 2008 and 2009 are 37.5 and 120 days respectively. Inability to pay the FJ$14 fee was not a major problem, on average resulting in between two and three days of power outage in 2008 and 2009. Likewise, inability to purchase an SHS code/token due to weather or other transport problems were not significant problems.

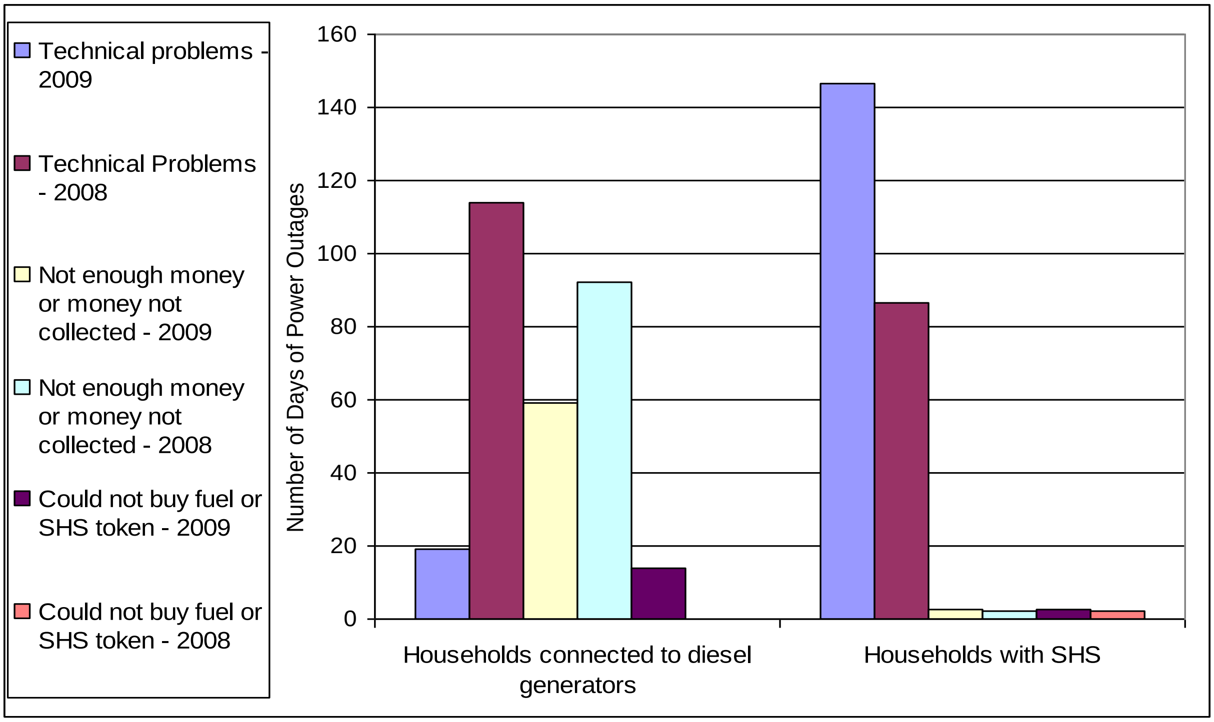
Technical problems were not as prevalent for the two diesel generators, although the generators in both Wairiki and Dama did suffer several long power outages in 2008. Interviews suggest that power outages of diesel generators commonly continued for many weeks due to delays in raising money for repairs through a *soli* (Interviews in Wairiki and Dama, November and December 2009).

Another problem was collecting enough money to purchase fuel for the generator. This was not necessarily the result of households not having sufficient money to contribute to a *soli* for fuel. Those amounts were lower than the fees paid for SHS, which were not an issue in either Nakawakawa or Vunivao. Rather, interviews revealed that the central problem was that provision of power from the generators was effectively a non-excludable good, with households receiving electricity regardless of whether or not they paid for fuel (Interviews in Wairiki and Dama, November and December 2009). All households surveyed in Dama and Wairiki supported this system, arguing that disconnection for non-payment was against "the village way of life".[146] At the same time, non-payment led both communities to trial different methods of collection to increase the amount of money raised for fuel, with collection methods changed when they were found to be ineffective. Collection of money for fuel became an important theme in village politics and debates in both communities. This is explored in chapter six.

Both Wairiki and Dama also suffered from a cyclone in January 2009 that blocked the road to the petrol station in Nabouwalu. Neither community was able to purchase fuel over a two week period as a result.

[146] This response was very common and was typically given when villagers wanted to communicate a notion they believed was alien to western culture.

Figure 5.5.2i. Reasons for Power Outages in 2008 and 2009 (average number of days in a given year)



Technical problems	2009	19	147
	2008	114	87
Not enough money or money not collected	2009	59	3
	2008	92	2
Could not buy fuel or SHS token	2009	14	3
	2008	0	2

Table 5.5.2d separates the data in figure 5.5.2i on the basis of each community surveyed, while combining power outages for 2008 and 2009 in order to simplify the table. It shows that results for Dama and Wairiki were relatively similar. Data for SHS on the other hand mask significant differences between answers in Vunivao and Nakawakawa. Households in Nakawakawa on average suffered less power outages in 2008 and 2009 than did any other community, although the figure was still relatively high at almost 140 days. Most of this was the result of technical problems, which on average caused 124 days of power outages. This average was significantly higher than the median, which was just 60 days in 2008 and was 0 days in 2009 (meaning that a majority of households in Nakawakawa did not suffer a power outage resulting from technical problems in 2009). Households had few issues in purchasing the SHS code/token, although sometimes affordability was a problem, as shown

by the average 14 days in which power was not available because households had not paid the SHS fee.

In comparison, the extent of power outages in Vunivao was more serious, owing almost totally to the impact of technical problems on SHS. This mirrors the data presented on longest power outages, which were also highest in Vunivao. Once again, the reasons for this relate to the failure of the *RESCO Program* to provide adequate maintenance and to address problems with prepayment meters. The survey results indicate that neither affordability nor purchasing of SHS were serious problems in Vunivao.

Table 5.5.2d. Power Outages Resulting from Different Reasons (Number of Days in 2008-09)

	Wairiki	Dama	Nakawakawa	Vunivao
Technical Problems	140	126	124	355
Could not afford fuel or SHS code/token	154	148	14	0.11
Could not purchase fuel or SHS code/ token due to weather or transport problems	14	14	2	6
Total	308	288	140	361

Households with SHS were asked whether maintenance under the *RESCO Program* was a) very satisfactory, b) satisfactory, or c) unsatisfactory. Based on the long periods during which electricity had been unavailable, it should come as no surprise that a majority of households considered the maintenance provided to be unsatisfactory. Not one household in Vunivao and less than one quarter of households in Nakawakawa considered maintenance satisfactory. This is shown in table 5.5.2e.

Table 5.5.2e. Opinions of SHS Maintenance

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

In summary, the survey results demonstrate the extent of power outages in both solar and diesel-based systems. Technical problems are responsible for the majority of power outages in SHS, given poor maintenance provision under the *RESCO Program*. Technical issues also affect diesel generators, with delays in collection of money for repairs extending periods where power is not available. The failure to collect sufficient money for fuel was the result of the non-excludable nature of power supplied through a village-based mini-grid system. These issues are explored in more detail in chapter six.

5.6 Conclusion

This chapter has provided an overview of rural electrification in Fiji. Extension of the FEA electricity grid has been the most common form of rural electrification, while in more remote off-grid areas, diesel and solar-based electrification has been common. Although there is information available on rural electrification in Fiji, there are significant gaps in knowledge. Survey, focus group and interview data presented in this chapter have sought to: identify the key threats to security of electricity supply in off-grid areas of Fiji; assess and compare the performance of the solar and diesel technologies that currently dominate off-grid electrification in Fiji; and explore the impact of high fuel prices on rural communities. The chapter has also looked at institutional arrangements for rural electrification and their impact on the security of electricity supplies.

The key findings of this chapter are listed below.

1. *Threats to security of electricity supply in rural areas are primarily supply-based* – The main causes of power outages in surveyed communities were technical (especially for SHS) or were the result of communities not collecting sufficient money to purchase fuel (for communities with diesel generators). Most households did not consider the cost of electricity a burden. In fact, access to electricity provided households with a cheap source of lighting and protected them from higher fuel prices, which would have affected them

more significantly if using kerosene or benzine for lighting. This was especially the case among households with SHS (diesel systems did not reduce fuel consumption to the same extent, as limited hours of operation require households to purchase lighting fuels).

2. *Institutional issues are paramount when considering power outages in rural areas* – Many of the underlying reasons for power outages were institutional in nature. In the case of the *RESCO Program*, the poor performance of SHS was caused by the failure of the *RESCO Program* to ensure provision of proper maintenance (or that prepayment meters that were suffering problems where replaced correctly). In the case of the two communities with diesel generators, the non-excludable nature of electricity supply prevented the collection of sufficient funds to purchase fuel, thereby resulting in power outages. These issues are explored in chapter six.

3. *High fuel prices have had negative economic and social impacts on rural households* – Un-electrified households in particular have suffered as a result of high fuel prices, with increases in expenditure on energy of up to 82 per cent. In households with access to an electricity supply, the affect has been more moderate (largely as a result of reduced reliance on lighting fuels). An interesting finding was that below average income households were marginally more affected in percentage terms than were average and above average income households, due to the large proportion of their total energy expenditure comprising kerosene and benzine.

Households in all communities climbed down the "energy ladder" as a result of high fuel prices, by reverting to cheaper and inferior sources of energy to meet their needs, and by reducing energy consumption. This means that threats to energy security more broadly (as opposed to security of electricity supply) are price-based. In the three indigenous Fijian communities, income data suggest that energy expenditure comprises approximately one-quarter of total household income when fuel prices are high. It is likely that below average income households are more affected by fuel prices than other households given the higher portion of their income that is spent on energy.

4. *Rural electrification programs need to meet varying levels of demand* – The survey results suggest that most households aspire to own appliances similar to those used by

households in urban areas. At the same time, many of these households will not be able to afford those appliances. This highlights the importance of offering different systems for households with different levels of income; something that can be readily addressed for SHS, although is more complicated for village diesel generators. Rural electrification in Fiji is unlikely to result in income generation in the short or medium term, but can have important quality of life and educational benefits for rural households.

The chapter that follows examines in more detail power generation and threats to power supply in off-grid areas of Fiji. It focuses on the institutional aspects of rural electrification, and uses that analysis to better explain the underlying reasons for power outages and the steps that can be taken to correct these problems.

Chapter 6

Analysis of Institutional Arrangements for Rural Electrification

An analysis of institutional arrangements for rural electrification is used in this chapter to explain fieldwork results presented in the previous chapter. Rural electrification using different technologies is examined under the *Rural Electrification Policy* and the *Renewable Energy Service Company (RESCO) Program*. The Institutional Analysis and Development (IAD) framework provides the conceptual framework for analysis. For diesel systems, the most important reason for power outages is the inability of communities to collect sufficient funds for fuel, which is a result of the non-excludability of village-based electricity provision. For solar systems, poor maintenance under the *RESCO Program* is due to information asymmetries and principal-agent problems. These issues are not resolved at the policy level.

6.1 Introduction

This chapter analyses institutional arrangements for rural electrification in order to better explain the interview, focus group discussion and survey results presented in chapter five. Rural electrification under two institutional arrangements is analysed: village diesel generators installed under the *Rural Electrification Policy* of 1993, and solar home systems put in place as part of the *Renewable Energy Service Company (RESCO) Program*. The Institutional Analysis and Development (IAD) framework, introduced in chapter two and used in chapter four, provides the conceptual framework for analysis. This takes place at two levels. At the operational level, the incentives of stakeholders and their impact on operation and maintenance are assessed. At the policy level, the reasons electrification programs are established in their current form are explored, as are the impacts of policy level decisions on security of electricity supply in rural off-grid areas.

Survey and interview information presented in chapter five identified the key threats to the security of electricity supply in off-grid diesel and solar-based electricity generation. For village-based diesel systems, the main reasons for power outages were the inability of communities to collect enough money to purchase fuel continuously, and technical problems with diesel generators. Failure to collect money for purchasing fuel was not necessarily because fuel was too expensive, although fieldwork results indicate that high fuel prices had some impact (for example, by reducing the number of hours that generators functioned). Respondents instead identified the bigger problem as being one of *collecting* sufficient money from households, which could generally afford to contribute but opted not to do so. This challenge stems from the non-excludability of electricity provision from the village diesel generation, with households receiving electricity regardless of whether they contributed to the pot of money used for fuel purchases.

For solar systems, the reasons for power outages were technical, underlying which was the inadequate provision of maintenance under the *RESCO Program*. A majority of survey respondents considered this maintenance unsatisfactory. The cost of electricity provided under solar home systems (SHS) did not appear to be a cause of energy insecurity. In fact, the opposite is true. Households with SHS showed lower levels of expenditure on energy than did un-electrified households, because of the fact they did not spend money on lighting fuels.

Placing these findings into the broader conceptual framework of this thesis, it appears that threats to energy security of off-grid electricity generation are primarily related to threats of cuts to physical supply. Technical issues are by far the greatest threat to security of electricity supplied by SHS, and are a significant threat to diesel-based electricity generation. The non-excludability of village-based electricity provision also results in power outages for diesel systems. Price-based threats to energy security are less important, though may have some impact on diesel-based generation. As a result, an analysis of the causes of energy insecurity of electricity supply in rural areas needs to focus on maintenance of both SHS and diesel systems, and the collection of money for diesel fuel purchases. Institutional arrangements governing these actions determine their success, and are therefore explored in some detail in this chapter.

The research questions addressed in this chapter are:

- What are the reasons for insecurity in electricity supply in off-grid areas?
- How do institutional structures impact the security of electricity supply?
- What is the impact of policy level decisions on off-grid generation in rural areas?
- Why were the *Rural Electrification Policy* and *RESCO Program* established in their current form?

6.2 Diesel-Based Off-Grid Electricity Generation

This section focuses on the operation and maintenance of diesel systems under the *Rural Electrification Policy*. The Institutional Analysis and Development (IAD) framework is employed in order to understand the behaviour and incentives of individuals and groups that come together in the relevant "action arenas". Incentives are sometimes economic; however more commonly at the village level they are social, cultural, and political. This highlights the importance of a broad interdisciplinary analysis. Decision making is influenced by a wide range of factors, which in keeping with the IAD framework, can be grouped as part of the physical world (including geography and resources) and the social world (which includes resource distribution, social norms, and the rules-in-use in any society). Action arenas do not exist in isolation, with different action arenas interacting and influencing one another.

6.2.1 Action Arena: Actors and the Action Situation

The installation of diesel systems installed under the *Rural Electrification Policy* occurs primarily in indigenous Fijian villages. Diesel generators are operated by a member of the village, trained by the Department of Energy in basic operation and maintenance of the generator when it is installed. The village purchases fuel, and is responsible for maintenance of the diesel generator after a three-year grace period (as outlined in chapter five). Different collection methods are used by villages in order to appropriate funds from households to pay for fuel and repair the generator.

The operational level of analysis is therefore firmly rooted in the village, and an understanding of village social structures is needed to explain both maintenance and operation of diesel generators. In the IAD framework, these social structures are termed rules-in-use, and include all forms of laws, informal rules and conventions that restrict and guide the actions of individuals. Ostrom (2005; 2001) argued that rules-in-use permeate all social relations, including market exchange. This is consistent with Polanyi's (1944) writings on social embeddedness, and also reflects recent work on the responsiveness of market exchange to social and cultural obligations in Melanesia (Curry 2003). In the case study, electricity generation in the village occurs within a broader framework of rules-in-use, which includes governance arrangements and gift-exchange in the village. Households contribute to electricity generation by providing money or labour towards fuel purchases, operation and repairs, and being involved to varying extents in the organisation of these activities. These responsibilities and actions form part of their broader interaction with the rest of the village.

Physical and social factors influence decisions taken within the "action arena" of electricity generation. A number of action situations involving electricity generation in the village can be identified. The first group involves the operation of the generator, and includes the collection of money from households to purchase diesel fuel, the identification of a collection system, and the physical operation of the generator. The second group involves maintenance of the generator, and includes provision of basic maintenance in the village, the organisation of generator repairs outside of the village, and collection of funds for maintenance.

There are many actors at the village level: the elected village committee responsible for organising generation; the village "technician" trained to operate the generator; the village treasurer who may have a role in collecting funds; the *turaga ni koro*, who is the elected village "headman"; and the *Tui* or village chief. The Department of Energy and private-sector mechanics involved in maintenance are also actors in the action arena.

6.2.2 Influences on the Action Arena (or Context): Physical Conditions, Attributes of Community and Rules-in-Use

Physical conditions, attributes of communities and rules-in-use frame electricity generation in the village. These influences on the action arena are discussed below under a number of themes, with special reference to remoteness and the nature of electricity provision, and social relations and decision making in surveyed indigenous Fijian villages.

Remoteness

The remoteness of many rural villages in Fiji is the primary physical condition affecting electricity provision, as it means villages cannot access the electricity grid. It also makes fuel prices higher and, in some cases, affects the supply of diesel fuel due to infrequent, and at times unreliable, transport (Interviews with Department of Energy, July 2009). Remoteness can also hamper the provision of maintenance, as it can be expensive and take time to have a mechanic travel to the village to inspect the generator and to supply spare parts. Distance from markets and poor transportation links also have wider detrimental economic impacts. The further removed communities are from markets, the less they receive for their produce, and the more expensive are the goods they purchase. This makes trade more difficult and less beneficial for them.[147] As detailed in chapter five, the two villages with diesel generators included in this fieldwork suffer from remoteness to some degree, although not to the extent of many more remote islands in the Fiji Island archipelago. Fuel can be purchased from nearby businesses.

Maintenance in Wairiki and Dama is different from most other villages in the area as both diesel generators in these villages were purchased under the pre-1993 *Rural Electrification*

[147] This point is highlighted by Ethrington (2006) in a discussion about villages that produce copra.

Policy. This enables the villages to pay the Department of Energy FJ$110 every year for basic maintenance. Repairs to the generator that are more expensive are still done by the Department (or in practice, frequently the Public Works Department), but are paid for by the village. Discussions with Department of Energy staff indicate that the system is a drain on Department resources as the cost of providing basic maintenance is considerably higher than the FJ$110 paid by villages. Elsewhere, more advanced repairs are either done by Indo-Fijian mechanics/farmers from nearby communities, or when repairs are more complicated still, by professional mechanics from Labasa.[148] Basic generator maintenance is commonly provided by village technicians.

A Common Good

Electricity provided through a village diesel generator can be considered a common good. A common good is: a) non-excludable, meaning that it is consumed simultaneously by the public, irrespective of whether individuals contribute resources towards the provision of that good, and b) rivalrous, meaning that consumption of the good by an individual subtracts from its consumption by another person. Excludability and rivalry are important in determining the characteristics of a good in economics (Buchanan 1965; Ostrom and Hess 2006; Samuelson 1954; Stiglitz 1999). The four types of goods commonly referred to in economic theory are illustrated in figure 6.2.2a.

Figure 6.2.2a Characteristics of Goods

	Excludable	Non-excludable
Rivalrous	Private goods Eg: food, cars	Common goods Eg: forest and marine resources
Non-rivalrous	Club goods Eg: golf courses, cable television	Public goods Eg: roads, law and order

Source: Adapted from Ostrom and Hess (2006)

The characteristics of a village diesel generator in Fiji are determined by social

[148] This can cause conflict. In Bua village, which I visited with Department of Energy personnel during fieldwork, villagers complained that an Indo-Fijian farmer was charging it exorbitant fees for repair of their generator. Department of Energy staff (all of whom were indigenous) travelled to the farmer's house to question him about the repairs, which were found to be in order.

arrangements at the village level. Social arrangements dictate that diesel generators in the villages surveyed for this research have the following common good features:

- Non-excludable

  A village diesel generator is excludable in a strict material sense, as a household can be physically disconnected. However, in the villages surveyed for this research, social arrangements dictate that households are never disconnected from the generator, as this "is not the village way" (Interviews in Dama and Wairiki, November 2009). Legally, tampering with power lines installed by the Department of Energy is also not allowed for safety reasons; although this is a side issue, given that other forms of tampering such as installation of lights are common practice. Social relations at the village level are therefore central to ensuring that electricity from diesel generators is non-excludable (despite the physical ability to disconnect households).

- Non-rivalrous

  A village diesel generator is rivalrous in so far as power consumed by a household can impact on power usage by other households. In both Wairiki and Dama, "power hungry" machines such as washing machines or irons short-circuit the ageing generators, and have led to village rules on appliances that can and cannot be used. These examples of rivalry suggest that electricity provision has "common good" features, requiring the establishment of rules regarding consumption of the good (Hardin 1968).

Economic theory states that public and common goods will not be provided to an extent that is welfare maximising, where marginal expenditure on the good equals the marginal return from the good, as individuals that contribute to the good's provision must bear all of the cost and receive only part of the benefit (Samuelson 1954). In other words, individuals have an incentive to "free ride" by not contributing to production of the good while nevertheless consuming that good. A good example of a public good is a road that passes through public land. Because anyone can access the road, no individual has an incentive to maintain the road. If they did, they would bear all of the cost, while other users that contributed nothing would benefit equally from their efforts. The result is that government provision of public goods which would otherwise be undersupplied is the norm (Samuelson 1954).

The "free rider" problem applies to all goods for which consumption is non-excludable. In relation to common goods, the economic literature generally focuses on common pool *resources*, given their importance and prevalence in the real world (Ostrom 1990). Difficulties in managing common good resources were famously described by Hardin in the *Tragedy of the Commons*, which discussed the destruction of grazing areas shared by herdsmen (Hardin 1968). The central problem with such "commons" was that consumption was non-excludable, meaning that individuals had no incentive to preserve or maintain such areas.

Mancur Olson extended the theory of "free riding" to all forms of group behaviour, even questioning the strength of voluntary action based on group associations to class or nation; actions which he argued are a form of public good (Olson 1965). He stated that "unless there is coercion or some other special device to make individuals act in their common interest, *rational, self-interested individuals will not act to achieve their common or group interests*" (Olson 1965: 2). With regard to small groups, Olson conceded that: "certain small groups can provide themselves with collective goods without relying on coercion or any positive inducements apart from the collective good itself" (Olson 1965: 33-34). However he argued that this was only the case "because in some small groups each of the members, or at least one of them, will find that his personal gain from having the collective good exceeds the total cost of providing some amount of the collective good" (Olson 1965: 33-34). In other words, individuals may provide some portion of a public good on a purely economic basis. However, at the same time:

> Even in the smallest groups … the collective good will not ordinarily be provided on an optimal scale…due to the fact that … other individuals in the group cannot be kept from consuming it once any individual in the group has provided it (Olson 1965: 34).

Although Olson's discussion is focused on public goods (which he terms collective goods), the discussion is equally relevant to common goods. The key issue in both cases is that consumption of goods is non-excludable, which results in "free riding" (or consumption of the good without associated payment or investment).

The experience of diesel-based generation in Dama and Wairiki, described in the preceding chapter, provides an interesting comparison to these arguments. Power outages in these villages can be explained to some extent by the non-excludability of electricity provided by diesel generators. Rural respondents stated that collection of money for fuel through a *soli* (a village collection) frequently failed to collect sufficient funds and that this resulted in periods where the generator was not run during its "agreed operational hours" of 6pm to 9pm.[149] They also said that in many cases this was not because households did not have money to contribute, but rather because households chose not to contribute.

This is consistent with Olson's argument. There was an undersupply of electricity, a common good, because households did not contribute the full amount asked of them under the *soli*. As a result, in both villages the process of collection became a political issue, with frequent changes in and debate about collection procedures. The election of the *turaga ni koro* was even influenced by a candidate's policy platform on his preferred collection method (Interviews in Dama and Wairiki, November 2009).

Public/common good theory does not tell the whole story. Despite the common good nature of diesel-based generation, both villages were able more often than not to purchase diesel fuel; about 80 per cent of the time according to the survey figures. This was achieved in a non-coercive manner, with no explicit punishment of non-contributors (although the most recent system in place in Wairiki does allow for the names of non-contributors to be read out in village meetings, providing a powerful social sanction). When villagers were asked why they contributed and why they did not punish non-contributors, the most common responses were that "we always come together in the village for these things", and that

[149] A *soli* is paid by households to a collective village pot of money on a regular basis for a range of reasons, including assistance for poorer families, contributions to the provincial council (known as the *Yasana*), and for hospitality to visitors to the village. Payment of money to purchase fuel for the diesel generator is also considered a *soli*, and has often in the past been combined with other *solis* and the money used by the village organising committee for various activities, including electricity generation.

punishment “was not the village way” (Interviews in Dama and Wairiki, November 2009). Clearly Olson’s description of limited provision of public/common goods on the basis of individual economic logic does not adequately describe these actions. A better theory for understanding these actions can be provided through an analysis of social relations in the village, with a particular focus on the important role of traditional gift-exchange obligations.

Social Structures and “Tradition” in Fiji

Most discussions of political and social organisation in the Pacific begin with Sahlin’s classic work (1963) on “political types” in the Pacific islands, which presents a dichotomy between political and social forms of organisation in Polynesia and Melanesia. Polynesian social structures, it argues, are characterised by stable, inequitable and hereditary hierarchies of chiefs, which are able to organise large numbers of people along semi-feudal lines. Melanesian social structures on the other hand are based on a more equitable “big man” system, where leadership is not ascribed but rather earned through gaining the support of the community. Because of the inherently personal nature of “big man” politics, leadership in Melanesia tends to occur on a small scale and is highly unstable, with ambitious men constantly competing for “big man” status.[150]

Fiji lies at the eastern margin of Melanesia and historically has been considered the dividing line between Melanesia and Polynesia. The Fijian landscape and the physical features of Fijians have more in common with those of Melanesia, but the hierarchical system of chiefs present in Fiji is more Polynesian than Melanesian. Accordingly, Fiji has commonly been described as Polynesian for the purpose of political and social structure (Chowning 1979).

There are significant differences between the eastern and western parts of Fiji, with the east more having more in common with Polynesia and the west and interior parts of Viti Levu

[150] Sahlin’s analysis, like that of earlier writings of European explorers, emphasised the superiority of Polynesian social organisation, considering it an evolutionary advance over Melanesian organisation. However Sahlin (1963) was also careful to emphasise that this distinction was one of “ideal types”, with there being “more of an upward west to east slope in political development in the southern Pacific than a step-like, quantum progression.”

considered more Melanesian. These differences can be explained by the successive Tongan (Polynesian) invasions of eastern Fiji, where Tongan nobles were installed as chiefs over Fijian villages (Brison 2007; Lasaqa 1984; Ross 1953; Sahlins 1962; Thomas 1989; Walsh 2006). Accordingly, federations of chiefly titles were prevalent in eastern Fiji, while smaller, less formal and sometimes non-hereditary chiefly structures dominated in western Fiji.[151]

The dichotomy drawn by Sahlins has not gone without criticism. Various authors argue that it misrepresents the complexity of social organisation in the Pacific islands. This complexity is illustrated in the many empirical studies of the region (Jolly 2007; Thomas 1989). In relation to Fiji, Thomas argues that:

> In unidimensional social evolutionary terms, eastern Fiji was 'Polynesian' because it was more hierarchical than western Fiji, but such an identification obscures the fact that the actual features and dynamics of the centralized Fijian confederations were entirely different to those of, say, Tongan polities (1989: 33).

The Polynesia/Melanesia dichotomy also ignores changes in social structures that have occurred since the colonisation of the Pacific islands. These changes have been particularly significant in the Fiji Islands, where the Deed of Cession effectively created a Fijian nation where none had previously existed (and notably occurred without the knowledge of western chiefs).[152] Nation building continued under Fiji's colonial administration, which promoted

[151] These differences also underlie many features of modern Fijian politics. One example is the failure of the western indigenous population to be represented by its own confederacy in the Great Council of Chiefs. It is currently represented by the Burebasaga Confederacy, the capital of which is in Rewa province, just north of Suva (in eastern Viti Levu). The differences also explain the lower levels of support among indigenous Fijians from the west for race-based indigenous political movements that use "tradition" as a rallying cry against so–called "Indian dominance" (Lal 1993; Lawson 1996; Thomas 1990).

[152] The cession of Fiji to the British Crown was agreed to by a number of prominent (mainly eastern) chiefs, particularly Ratu Seru Epenisa Cakobau of the Eastern island of Bau. Cakobau offered Fiji to the British because his government (supported by European settlers) had amounted unmanageable debts and his self-proclaimed title "Tui Viti" (King of Fiji – a term first used in a letter from a European seeking favours from Cakobau) was being challenged by other indigenous groups in Fiji. Cakobau had first approached the British 12 years earlier in order to gain their help to pay off a debt to the American ambassador, whose residence had been destroyed in an act of arson. On that occasion, he had offered 5,000 square kilometres of land, an offer that was rejected by the British crown but accepted by the Australian-based Polynesia company, and led to the establishment of a Constitutional Monarchy with a legislative assembly and executive dominated by white settlers, which was based in Levuka. The Deed of Cession officially made Fiji a British colony, and under the first substantive governor, Sir Arthur Gordon, protected indigenous Fijians from the often-exploitative practices of white settlers under a policy of "Fiji for Fijians" (Lasaqa 1984; Ratuva 1999; Sahlins 1962).

and spread systems of social organisation present in Bau to the rest of the Fiji Islands. Bauan Fijian (related but not the same as other indigenous languages in Fiji) became the common language, while the indigenous government structures that were set up in the form of the Council of Chiefs (the precursor to the present Great Council of Chiefs) and at the Provincial level mirrored traditional social structures in Bau. Land was also established as inalienable, with ownership vested in *mataqali* (or clan) groups (Tanner 2007; Walter 1978).

"Traditional" social structures are therefore not necessarily the same social structures that were present in pre-colonial times (Lawson 1996; Sahlins 1962). Many social structures from Bau have been imposed on other parts of the Fiji Islands, while some completely new "traditional" arrangements have been created.[153] The establishment of these "traditional" structures has commonly occurred and/or been exploited for political purposes (Ratuva 1999). "Tradition" has been used historically to promote both the interests of indigenous Fijians over those of Indo-Fijians, and the interests of the indigenous elite over commoners (Lawson 1996). For example, the inalienability of indigenous *mataqali*-based land ownership has been promoted for reasons of tradition in Fiji, despite the fact that the system was developed by the colonial administration (Lasaqa 1984). Land reform has subsequently been portrayed by indigenous Fijian leaders as a threat to indigenous Fijian interests, negating all types of land reform. This entrenches the existing system where most rental income is accrued by *mataqali* leaders and chiefly elites, not indigenous commoners (Lawson 1996; Ratuva 1999).

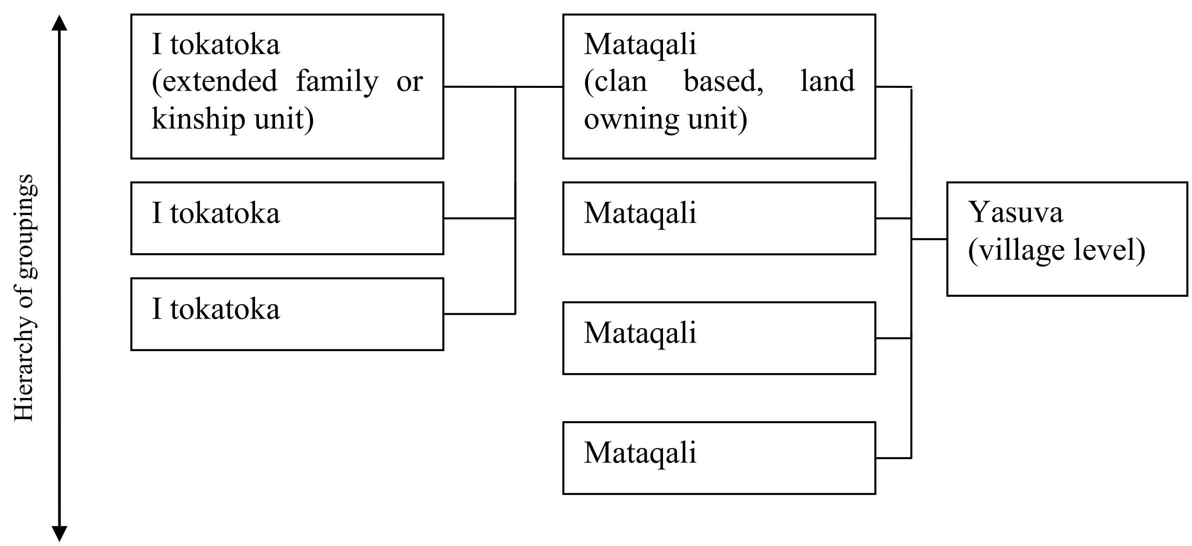
Chiefly Status and Governance

Social organisation in Dama and Wairiki (and Nakawakawa) is situated within the context of the eastern Fijian Tovata Confederacy, the most Polynesian of the three indigenous Fijian confederacies. The Tovata Confederacy is based on a strict hierarchy of chiefs, with

[153] New institutional arrangements include the fairly rigid collective land ownership framework, which while administratively convenient, contrasted with previous (much more flexible) practices where land was commonly shared among different *mataqali* and villages migrated regularly; both in Bau and in most other parts of Fiji (Tanner 2007; Walter 1978). Also new is Provincial Administration, which is based on (sometimes existing) chiefly hierarchy (Sahlins 1962).

chiefly succession being hereditary and limited to males.[154] In the Tovata Confederacy, a village usually equates to one *yasuva*. Each *yasuva* is comprised of a number of land-owning *mataqali* groups, which in turn are made up of a number of extended family units called *i tokatoka*. Hierarchy extends to all groupings. This means that certain *i tokatoka* are senior to others within a *mataqali*, with the leader of the senior *i tokatoka* normally being the leader of the *mataqali*. Similarly, *mataqali* are ranked, with the highest ranking *mataqali* called the "chiefly" or *turaga mataqali*.[155] The village chief is normally the most senior person in the chiefly *mataqali* (Ishii 1998). These arrangements are illustrated in figure 6.2.2b

Figure 6.2.2b Indigenous Fijian Social Organisation



Source: Adapted from Ishii (1998) and Ratuva (1999)

[154] Its Paramount Chief (the Tui Cakau) is based in Taveuni. The Tovata Confederacy has been particularly influential in modern times, with both "fathers" of Fiji, Ratu Sir Lala Sukuna and Ratu Kamisese Mara members of the Confederacy (Lal 1993; Lawson 1996; Thomas 1990).

[155] This does not equate to a noble class as is the case elsewhere in Polynesia (despite claims of a caste system by Hocart in his early ethnographies of Fiji).

A strong chiefly system does not necessarily mean overbearing chiefly direction of everyday activities, nor lack of community participation in decision making. As argued by Lasaqa, such an interpretation:

> ignores the consultation and discussion that goes on at all levels of Fijian society on a variety of issues, and which are often keen and intense, between people and chiefs, through accepted procedures, before a firm decision is taken and action follows (1984: 24).

Chiefs need the support of their people, and cannot rule by hereditary status alone (Kawai 1998; Ross 1953).

It is actually more common than not for chiefs to remove themselves from everyday village affairs, as this is seen as further enhancing their authority (Ishii 1998). Brison therefore observes that "senior men … used the discourse of consensus and tradition to advance their own reputation in an arena where restraint and distance from conflict were taken as sign of high status" (2007: 18). Chiefly involvement in argument or debate in this context is seen as "un-chiefly", especially when it relates to everyday activity (Arno 1985).

In practice, the *turaga ni koro* (meaning "leader of the village") commonly replaces the chief in ordering everyday activity in the village (Biturogoiwasa and Walker 2001; Ishii 1998). The *turaga ni koro* is a village member who is democratically elected by male members of the village to represent it in dealings with the government.[156] The occupant is always male and is frequently although not always from the chiefly *mataqali* (as was the case in Dama and Wairiki). The *turaga ni koro* commonly organises village meetings, the communal village work program, and hospitality to guests (such as occurred with my visits). A village committee assists the *turaga ni koro* to organise everyday activity in the village, and like him, is also elected by the village (in Dama and Wairiki each *mataqali* has

[156] The position of *turaga ni koro* was also created by the colonial government and remains in place today (with persons elected to the position paid a small monthly allowance by government). This new position has been incredibly important to everyday Fijian village life. Several authors argue that its introduction has reduced the role of village chiefs, which used to be more involved in day to day affairs, albeit generally through the leader of the "spokesperson" or *sauturaga mataqali* (Biturogoiwasa and Walker 2001; Henrich and Henrich 2006).

a number of representatives on the committee).[157] The village committee specifies responsibilities for each member, such as “village treasurer” and “organiser of sanitation”.

The result is that despite the hierarchical nature of the chiefly system in eastern Fiji, the organisation of everyday affairs involves considerable community participation. Chiefs involve themselves primarily in “important” issues at a higher level, such as relations with other chiefs, succession and land disputes. When discussing everyday issues however, chiefs are absent, and if involved at all, tend to govern using consensus and a high degree of community participation (voiced appropriately). In these arenas, the democratically elected (albeit by males only) *turaga ni koro* and village committee members have greater influence.

Decision making in Dama and Wairiki

In Dama and Wairiki, social organisation loosely follows the patterns described above. Each village has a chief (the most senior member of the chiefly *mataqali*), a *turaga ni koro* and a village committee, the last two of which are elected annually by all adult males resident in the village. The respective roles of the chief and the *turaga ni koro* differ in the two villages. In Dama, the chief is removed from everyday affairs and the role of the *turaga ni koro* in organising village life is considerable. This does not occur to the same extent in Wairiki, where the chief is more involved in day to day activities and the *turaga ni koro* has less responsibility.

Collection of money for diesel fuel for the generator is an important subject of discussion in village level politics in Dama and Wairiki. Collection systems in both villages change over time, with a tendency for systems to work periodically and be replaced when they cease to function. In Dama, collection systems formed one of the election promises of the *turaga ni koro*, who established a rotating system where two households would share the FJ$4 cost of purchasing diesel fuel each night. Previously, funds were collected from all households in the village each week, however the system did not work well (Interviews in

[157] In Dama, four *mataqali* have two members each in the eight-person committee, while in Wairiki five *mataqali* have one member each in the five-person committee. The *turaga ni koro* is automatically a member of the village committee.

Dama, November 2009). Survey and interview data shows that during this period some households contributed significant amounts of money (up to FJ$60 per month) to ensure that fuel was purchased, commonly because they had children and wanted them to complete their homework (Interviews and Survey in Dama, November 2009). The village was nonetheless frequently unable to purchase sufficient fuel for the generator. The current system is “much better” according to most respondents, and it is clear that the status of the *turaga ni koro* had improved as a result of the change.

In Wairiki, the *turaga ni koro* was not directly linked to any one collection system, but the system was modified frequently as a result of discussion and complaints voiced in village meetings. The village treasurer and *turaga ni koro* provided a detailed history of the collection systems used in the recent past (table 6.2.2a), together with their perception of the reasons each system had failed. Survey respondents had opposing views about each system, and this was a point of discussion at monthly village meetings. As in Dama, the method used to decide on a collection system was democratic, with the village council first discussing new alternatives, and then taking proposals to village meetings for a vote (Interviews in Wairiki, November 2009).

Table 6.2.2a. Collection Systems used in Wairiki

Period	System	Results
2006	Money was collected on the basis of the number of lights in a person's house ($2 per fluorescent light).	Changed as not affordable to some families.
2006 – 2007	Collection of about $10 per households to buy a 44 gallon drum (the actual amount given depended on the household). Before the drum ran out another collection would take place to buy the next drum.	Households did not always contribute the $10 so there would often be no electricity.
2008 (3 months)	Collection of $2 per household every week, which would buy a 20L of diesel.	Very unsuccessful. People would forget (and instead buy cigarettes).
2008 (3 months)	One household would buy 1 gallon of diesel each night on a rotating basis.	Families would fail to purchase the fuel – it was unaffordable to many.
June 2008 – August 2009	Collection of $10 per household each month	Households did not always contribute the $10 so there would often be no electricity. It was a lot of money in one payment.
Aug 2009 – now	Collection of $5 per households each fortnight, with some poorer households paying $2 per week. Under this system, the treasurer keeps a record of those who have been giving the $5 a fortnight, and reads out the names of those who have not paid at the monthly village meeting.	Successful to date. The treasurer (who introduced the system) proudly said: "Often those people whose name is read out are the first to pay the following month."

Gift-exchange

The impact and design of collection systems for purchasing diesel fuel in Dama and Wairiki are influenced by gift-exchange under the *kerekere* system. Gift-exchange obligations under the *kerekere* system are an important feature of village social organisation throughout the Fiji Islands. The *kerekere* system enables others in the village, particularly members of the same *mataqali* or *i tokatoka* to ask for a range of items. It is difficult and in many cases almost impossible for a household to refuse those demands without disregarding social obligations, which is unlikely given their important role in social welfare provision and maintaining social cohesion (Rutz 1978; Sahlins 1962; Spate, et al. 1960; Turner 1987).

This was also the case in Wairiki and Dama, where villagers felt compelled to share items and seldom refused a request, as this would create conflict. Items that were commonly shared included: food, fuel, cigarettes, kava and even money (Interviews in Dama and Wairiki, November 2009). Households shared these items on the understanding that if they ever lacked anything, a similar claim could be made for goods from other households.

The *kerekere* system is an important part of indigenous Fijian identity, and was frequently contrasted by villagers against "individual" and "selfish" Western or Indian culture (Interviews in Dama, Wairiki and Nakawakawa, November and December 2009). The *kerekere* system has retained its importance for indigenous identity since colonisation. Indeed, it is commonly argued that gift-exchange under the *kerekere* system has increased in recent decades (Biturogoiwasa and Walker 2001; Ishii 1998; Lasaqa 1984; Rutz 1978).

6.2.3 Patterns of Interaction and Incentives

Collection of Money for Fuel Purchases

The *kerekere* system is the key to understanding why sufficient money for diesel fuel is collected about 80 per cent of the time, despite the non-excludability of electricity provision in the village. Olson's conclusions that people will not contribute to provision of a non-excludable good, except to the extent they serve an economic motive, is in essence a simple one-off "game" resulting in Nash equilibrium.[158] In that game, nobody contributes to a non-excludable good as they receive the benefit of the good regardless of whether or not they contribute. Where somebody does contribute in a small community, it is only because the provision of a good is of greater benefit than cost to that individual. The problem with such a game is that it ignores the long run nature of the game, and the influence of social and cultural norms, or rules-in-use. These rules impact on incentives in

[158] In Game Theory, Nash equilibrium refers to a situation where players in a "game" choose a strategy and have nothing to gain by changing their strategy while the strategies of other players remain unchanged. A common example of Nash equilibrium is in a "Prisoner's Dilemma" game, where players have an incentive to "defect" and blame the other player for a crime.

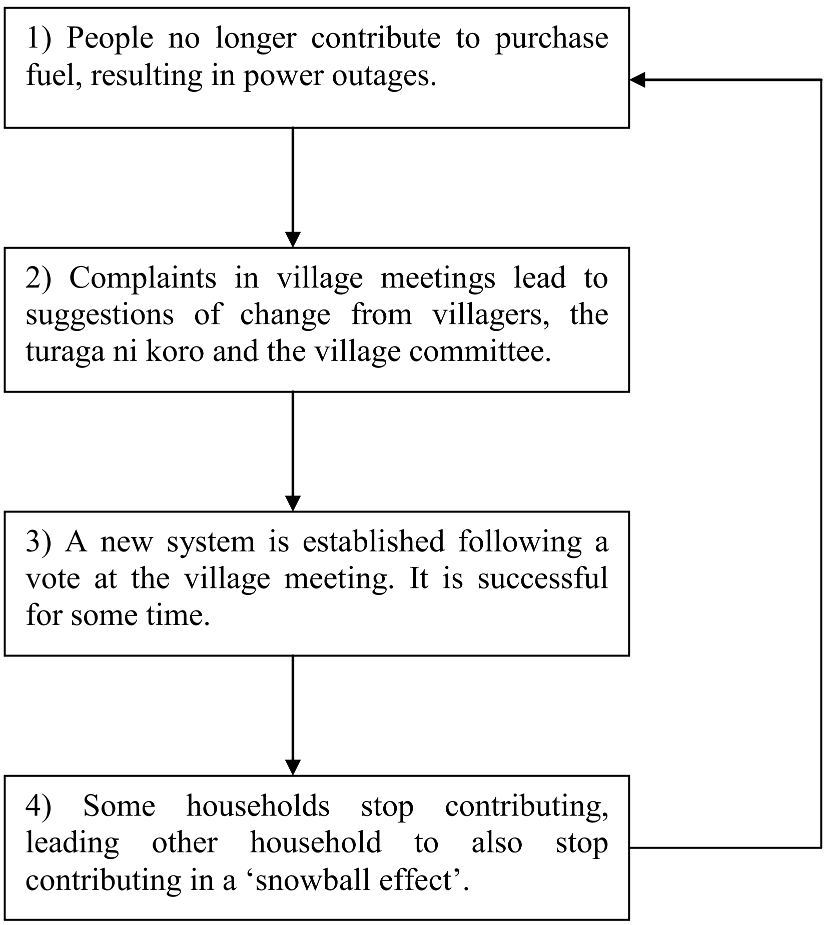
two ways. First, people have an incentive to adhere to rules-in-use over the long run because of fear of reprisals, such as social ostracism or the inability to secure goods under the *kerekere* system. This can be represented in game theory where the game is repeated. Second, cultural norms and rules-in-use engender systems of belief that are taught and reproduced through everyday activity. These beliefs impact on the internal calculation/ordering of incentives by individuals that have bounded rationality.

The *kerekere* system had a direct impact on whether households contributed to the collection of funds for diesel fuel in Dama and Wairiki. In interviews, households frequently said that they contributed for two households if their neighbour or another villager could not afford to make the payment (Interviews in Dama and Wairiki, November 2009). The influence of the *kerekere* system on village social life also explains why people were not punished for not contributing to the collection of money for fuel. Most households surveyed admitted that other households at times did not contribute even where they had sufficient money, but this did not lead to punishment or even a verbal complaint. Complaining was described several times in interviews as contrary to "the village way", with the explanation being that it would cause conflict that would undermine (cooperative) village life (Interviews in Dama and Wairiki, November 2009).

This is not to say that rules-in-use are absolute. Clearly when it comes to the collection of money for diesel fuel they are not. Short term considerations commonly did play a role, providing villagers with incentives to defect from contributing occasionally without fear of punishment. Olson is therefore correct when he asserts that non-excludable goods will be undersupplied in a small group (with marginal return from supplying the good being higher than the marginal cost on a supply demand curve). However his treatment of the game as short term and based only on economic rationale limits the validity of his broader conclusions. In the long run, external pressures (the risk of social ostracism) and internal value systems that consider the *kerekere* system important and beneficial have a more significant impact. In the context of purchasing fuel in Dama and Wairiki, this means that only sometimes is the collection of funds to purchase fuel insufficient.

Game theory is more useful in explaining the frequent changes in village collection methods, provided the game (of whether to contribute or not) is treated as a repeated game in the long run. Discussion of the history of collection methods in Wairiki with the treasurer and *turaga ni koro* identified several steps that are experienced whenever a collection method is changed (see figure 6.2.3a). The important issue to note is that the actions of players depend on their expectation of the actions of others; they do not want to be the only household contributing money. This is consistent with a repeated game in game theory. Thus, new systems would work for a time, but when some households stopped contributing, others would also stop and the system would cease to function.

Figure 6.2.3a Common steps in change to collection methods in Wairiki



This explanation appears to contradict the claims of households that they contributed on behalf of neighbours when their neighbours could not. However the apparent contradiction is explained by a distinction between the short and long run (or single and repeated games). In the short run, households are willing to contribute on behalf of other households that do not contribute, consistent with the *kerekere* system. In the long run however, the *kerekere* system is based on reciprocation. Providing someone with something generates an obligation on the part of the recipient to provide something in return in the future. In the long run therefore, households will stop contributing if other households refuse to contribute.

The success of a collection system and the decision about whether to contribute were also linked to village level politics. As described earlier, the process of deciding on a collection method was highly democratic. Collection systems were decided on by the village committee and *turaga ni koro*, and were voted on in village meetings. The village committee and *turaga ni koro* both had an interest in promoting a workable system, as this could increase their support base. Enthusiasm for a collection method was also likely to be linked to the closeness of a household with the proponent of that system, be it the *turaga ni koro* or a certain member of the village committee (this was supported by interview data). The decision to contribute to fuel purchasing is therefore linked to village level politics, including household identification with groups within the village, such as certain *i tokatoka* and *mataqali*.

Operation and Maintenance of the Diesel Generator

Similar dynamics can be seen in the maintenance and operation of the diesel generator. The operator of the generator in both Dama and Wairiki performs the role without payment.[159] This can be considered a form of gift-exchange that is a variant of the *kerekere* system, as it involves the exchange of services rather than goods.

External maintenance is paid for through a village collection or *soli*, whereby each house contributes a set amount to a pot of money that is used for maintenance (with leftovers kept by the village treasurer and used for other village expenditure, such as fuel). As with the purchase of fuel, not all households contribute the full amount, but there is a high collection rate and the necessary money is collected more often than not, albeit sometimes with a

[159] In Wairiki, the *turaga ni koro* considers operating the generator part of his responsibilities as *turaga ni koro* (for which he is paid a small allowance by the government). He has been trained by other villagers who attended Department of Energy workshops. In Dama, the operator is a villager trained directly by the Department of Energy in how to operate and provide basic maintenance to the generator. He performs the role as part of his contribution to the village, and in return, others plant some of his crops.

delay. The delay in collecting money means that village generators can be non-operational for several months (as shown in chapter five). The same collection system is used to pay the Department of Energy FJ$110 annually for basic maintenance.[160] That collection involves less money but is normally less successful, probably because it is seen as less urgent to the functioning of the generator (although in the long term failure to provide basic maintenance can be more costly).[161]

The village committee similarly decides hours of operation of the generator, although the matter is normally also discussed and voted on in a village meeting. In both villages, normal operating hours at the time of the survey were between 6pm and 9pm, which includes the three hours immediately after sunset. In special circumstances, operating hours can be extended all night, as occurs on Christmas and New Years Eve. On these occasions the village uses a *soli* to collect additional money for fuel. Other occasions for extending operating hours include funerals and weddings, although the fuel for these events is normally purchased by the extended family (*i tokatoka*) of the deceased or recently wed (Interviews in Dama and Wairiki, November and December 2009). The committees in Dama and Wairiki also limit the use of power hungry machines that can short-circuit the system (the use of irons and washing machines is therefore rarely permitted).

6.2.4 Outcomes

This section has discussed the attributes of diesel-based generation in Wairiki and Dama, with particular reference to governance structures, decision making, and gift-exchange. Power is not always available between 6pm and 9pm in either village, due to the failure to collect sufficient funds to purchase diesel fuel or repair the generator. Nevertheless, power is available more than the economic theory of non-excludable goods would suggest. Collection of money meanwhile has become linked to village-level politics in both

[160] Technicians from the Department of Energy perform repairs in a satisfactory manner, as failure to do so could potentially result in a complaint to Departmental management by the village *turaga ni koro*.
[161] An interesting comparison can be made with collection of money from the village to fund the *Yasana* (or Provincial Council). That contribution is essentially a tax, however because it is viewed as “traditional”, collection rates are reported as normally higher (Interviews in Dama and Wairiki, November 2009).

locations, with new collection methods determined through a highly political process. The non-excludable nature of electricity from a diesel generator is taken as given by both communities and there are no attempts to exclude and few attempts to penalise people for non-payment. This is due primarily to what is referred to as the "village way", a reference to the importance of gift-exchange obligations and its role in social cohesion.

Diesel-based electricity generation in the village is therefore socially embedded. Social relations are central to explaining all aspects of diesel-based generation, from the collection of money for fuel, through to the operation and maintenance of the generator. Rural electrification conversely also has an impact on village social structures. Policy makers need to be aware of and consider the impact of these social relations on electricity generation when establishing policies for rural electrification.

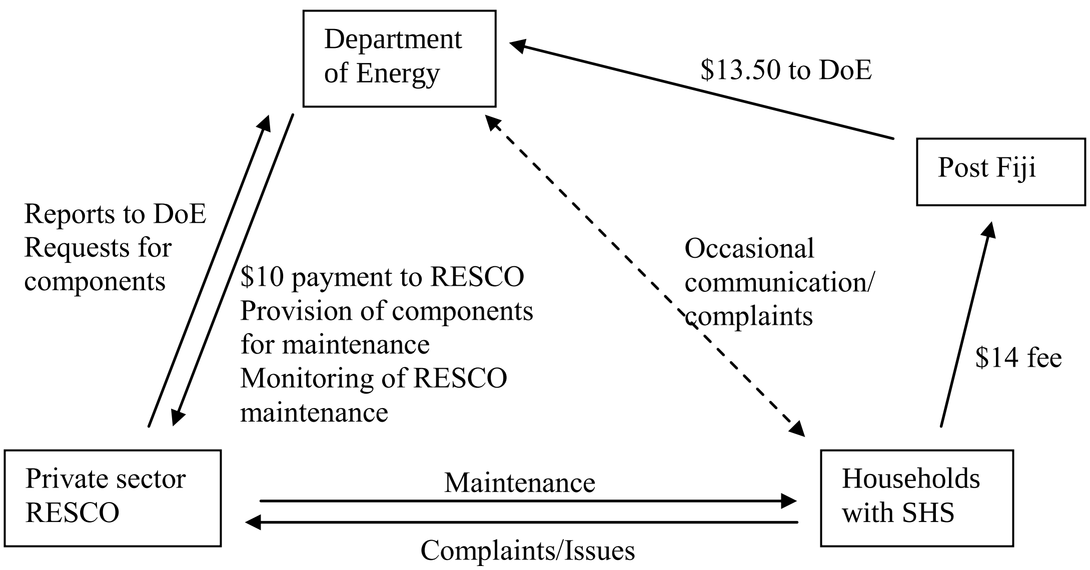
6.3 Solar-Based Electricity Generation

This section discusses solar-based off-grid electricity generation in Fiji. Its focus is the operation and maintenance of SHS installed under the *RESCO Program*. Approximately 1,600 solar home systems (SHS) have been installed in Vanua Levu since 2000 under a pilot phase of the *RESCO Program*. The program is now being expanded to the rest of the Fiji Islands.

6.3.1 Action Arena: Actors and the Action Situation

Under the *RESCO Program*, users pay the Department of Energy through Fiji Post a monthly fee to access electricity (as described in chapter five). The Department then pays the RESCO approximately FJ$10 per month for each household under its maintenance contract. Payments to the RESCO are made every two months, during which time the RESCO is expected to visit every household with a SHS once. During these visits, technicians check the water levels of batteries and test the output of the batteries and panels. Where batteries or lights have failed, RESCO technicians make a note and report this to the Department of Energy in their report. The Department of Energy is responsible for purchasing new batteries and light bulbs (as well as other necessary equipment), and sends these to the RESCO for installation in their next round of maintenance visits. A simple diagram of the role of each group in the maintenance system is provided in figure 6.3.1a.

Figure 6.3.1a. The *RESCO Program*



It is clear that the RESCO plays the central role in the program, providing maintenance to systems, reporting issues to the Department of Energy, and acting as the primary contact point for households with SHS. The Department's main roles are the purchasing of replacement components, and the monitoring and payment of the RESCO. These roles are outlined in contractual agreements between the Department and the RESCO. Households play a relatively passive role. Households sign a contract with the Department of Energy on installation of the SHS, stating that the SHS remains the property of the Department, technicians are allowed access to the SHS, and households will not tamper with the system.

The action situation of most relevance to this study is the maintenance of SHS by the RESCO. Of particular importance is the relationship between the Department of Energy and the RESCO. The RESCO is contracted by the Department to perform maintenance, and failure to perform that role is the result of poor monitoring and penalisation of the RESCO. The characteristics of community governance and social structures are not particularly important for the *RESCO Program*, as maintenance is removed from the household level. This differs considerably from operation and maintenance of diesel systems within a village. Other issues that impact on SHS maintenance include: Department of Energy purchases of SHS components; Department relations with the RESCO, including payments; and on occasions, tampering by households that can affect SHS performance.

6.3.2 Influence on Action Arena (or Context): Physical Conditions, Attributes of Community and Rules-in-Use

Influences on the action arena are central to understanding performance of the *RESCO Program* in Fiji. In particular, attributes of the Department of Energy and the RESCO, and interaction between these two organisations, and between management and staff within each organisation, explain the poor maintenance of SHS identified in fieldwork presented in chapter five.

Problems of Trust

A lack of trust underlies interaction between stakeholders in the *RESCO Program*. Coleman (1988) argues that trust can be voluntary or enforceable. Voluntary trust exists where parties trust one another to act in a way that is agreed on by both of them. Trust facilitates the organisation and performance of the action, and is therefore a form of social capital. In fact voluntary trust can also be considered a public good, as it is accessible by all but the “cost” must be paid by individuals who act honestly (Coleman 1988; OECD 2001). Voluntary trust is therefore an important feature of market economies, and in its absence, “markets would operate in a much more cumbersome, much less efficient fashion” (Coleman 1988: 98). Where voluntary trust is insufficient for a transaction to occur, enforceable trust is commonly relied upon. Enforceable trust is established by an arrangement that places penalties on parties that renege on an agreement. Contracts are a common source of enforceable trust, ensuring that parties adhere to an agreement.

Both forms of trust were lacking in relations between the Department of Energy and the RESCO. In interviews, Department of Energy staff were clearly distrustful of reports coming from the RESCO and did not believe it was performing maintenance adequately. Conversely, the RESCO was distrustful of the Department's ability to administer the *RESCO Program*, citing delays in payments and periods where it was left without a contract. Households with SHS were distrustful of both the RESCO and the Department. Various households accused RESCO technicians of laziness and in some cases theft, while others argued that it was difficult to know who was at fault given it was the word of the Department against that of the RESCO. Conflict between the RESCO and the Department further reduced levels of voluntary trust.

Enforceable trust was also low between the two parties, as monitoring of RESCO maintenance by the Department was difficult. This was due to two reasons. First, the contract between the Department and RESCO was far from comprehensive (as described below), and second, the remoteness of areas where maintenance was provided made it difficult for the Department to visit households with SHS. Difficulty in monitoring RESCO maintenance was made worse by under-resourcing of the Department of Energy, which was not provided with staff or a budget for the role, and instead had to draw on its core budget/staff and those of the Rural Electrification Unit (which was not responsible for the *RESCO Program*). These difficulties resulted in information asymmetries between the Department and the RESCO, which explain poor maintenance under the program in the absence of voluntary trust. Information asymmetries created a number of principal-agent and motivational problems in the administration of the RESCO model, and were also potentially a source of conflict between key stakeholders.

Principal-Agent Problems

Principal-agent situations occur where the incentives and goals of the principal differ from those of agents. In a principal-agent situation, the principal is the stakeholder that directs and benefits from the outcomes achieved, while the agent is employed by the principal to perform actions that will result in that outcome. A common principal-agent relationship exists where work is outsourced to a contractor, which performs a role specified by its employer (the principal). Many economic models work under the assumption that the principal (the party that provides the contract) knows what tasks need to be performed and how to ensure that subordinates (or the contracted party) actually complete those tasks. However the analysis of principal-agent situations acknowledges that this does not occur perfectly in the real world, and that principal-agent problems negatively affect outcomes in most situations where one group (the principal) employs another (the agent). There is now a rich literature about principal-agent problems in a range of everyday situations, including doctor-patient, lawyer-client, and contractual relations (Ostrom, et al. 2001).

The main cause of principal-agent situations are information asymmetries that exist between the principal and the agent. In most principal-agent situations, agents will have more information relating to their actions than will the principal. Indeed, commonly the agent is the main source of information for the principal. The agent will generally have incentives to pass on only information that is favourable to it, meaning that the principal receives not only incomplete, but also biased information about the actions the agent has performed on its behalf.

Information asymmetries also affect the incentives of the agent. Where an agent believes it can minimise its work without the principal realising, it has an incentive to do so, as the agent does not benefit from the outcome in the same way as the principal. A range of measures has been created to help overcome principal-agent problems. Monitoring and penalty provisions in contracts are one example, as are licensing of doctors and other professionals and tradespersons, and the issuance of shares to employees by companies.

The *RESCO Program* displays principal-agent problems at several levels. The most obvious exists between the Department of Energy and the RESCO that is contracted to provide the maintenance service. The main goal of the private sector RESCO is profit.[162] RESCO management and staff are not part of the communities where SHS are installed, and so social obligations at the community level are not relevant.[163] The profit motive means that RESCO management aims to operate as cost-effectively as possible with as few a staff as necessary, and to meet contractual obligations to ensure that the RESCO is paid, penalties are avoided, and its contract is renewed. However information asymmetries prevent the Department of Energy from knowing the exact standard or amount of work that the RESCO performs. The incentive of the RESCO therefore becomes one of *appearing* to the Department as if it is meeting contractual obligations. Whether this means it actually meets contractual obligations depends in large part on the monitoring systems and penalty provisions put in place by the Department.

Monitoring and penalty provisions normally form part of the contract between the principal and the agent, and can establish enforceable trust in order to ensure that the agent performs the task to the standard required and expected by the principal. Unfortunately the contract in place between the Department of Energy and the previous RESCO was deficient in key areas. In particular, it lacked detail about the monitoring provisions that the Department would employ, certain responsibilities of the RESCO (such as the replacement of batteries), and penalty provisions, which were not understood by the RESCO. Monitoring of RESCO maintenance was strengthened in 2008 when the Department installed logbooks in households, however these were focused on visits to households rather than the functionality of SHS. This system provided the RESCO with incentives to visit all houses (and sign the logbooks), but not to do major work as part of those maintenance visits.

[162] Other incentives also exist, such as meeting the needs of customers and ensuring the success of SHS. These can be important, but will generally come second to profitability, which is needed for the RESCO to survive.

[163] Previously a technician from a local community provided maintenance. A conflict in 2005 however led to an act of arson in which the technician lost his home and the RESCO and Department lost thousands of dollars of SHS equipment. The system was abandoned as a result. RESCO management also explained that it found it difficult to trust technicians based in communities as their loyalties were to the community and not the RESCO. This led to dishonest practices, such as failures to penalise households for tampering, and provision of “free” electricity where systems were falsely reported as having not been operational (Interview with RESCO management, December 2009).

Difficulties in monitoring RESCO maintenance were compounded by the lack of resources made available to the Department of Energy for the role. In interviews, the RESCO was critical of the Department's administration of the RESCO scheme, which it claimed delayed payments to the RESCO, resulted in a period where the RESCO had no contract, and did not deliver spare parts in a timely manner (Interview with RESCO management, December 2009). Department of Energy staff and management conceded that budgetary reasons partially explained these problems (Interviews with Department of Energy staff and management, November and December 2009). The budget provided to the Department for the administration of the *RESCO Program* was inadequate (Wade, et al. 2006), and remains so today with the Department's overall budget further reduced in 2010. Department of Energy staff involved in the *RESCO Program* have many other responsibilities and are only able to work part-time on the *RESCO Program*. Indeed, the Department has had to dedicate staff from other areas to ensure that monitoring of RESCO maintenance takes place. The manager of the *RESCO Program* in the Department of Energy is in the same situation, with many other equally pressing responsibilities (Interviews with Department of Energy staff, November and December 2009).

Motivational Problems

Resourcing issues are likely also to affect administration of the *RESCO Program* through "motivational problems". Motivational problems are a variant of the principal-agent problem, and occur when employers or management in hierarchical organisations cannot verify whether employees have completed the tasks asked of them, negatively affecting their performance (Alchian and Demsetz 1972). All hierarchies face motivational problems to some extent, with the primary cause being information asymmetries between management (the principal) and employees (the agents). As employees do not share in the full benefit of the outcome achieved by the organisation, they have less incentive to complete the work that is asked of them.

The impact of motivational problems depends in large part on the monitoring systems and penalties put in place by management to address them. Where monitoring systems and penalties are effective, the worst effects of motivational problems can be overcome. Ostrom et al. note that motivational problems in organisations are enhanced by activities forming only part of the responsibilities of staff, high staff turnover, career advancement that is not directly related to performance in the specified task, and the size of the organisation (Ostrom, et al. 2001). The first three features are present in the Fiji Department of Energy.

Moral Hazard Issues

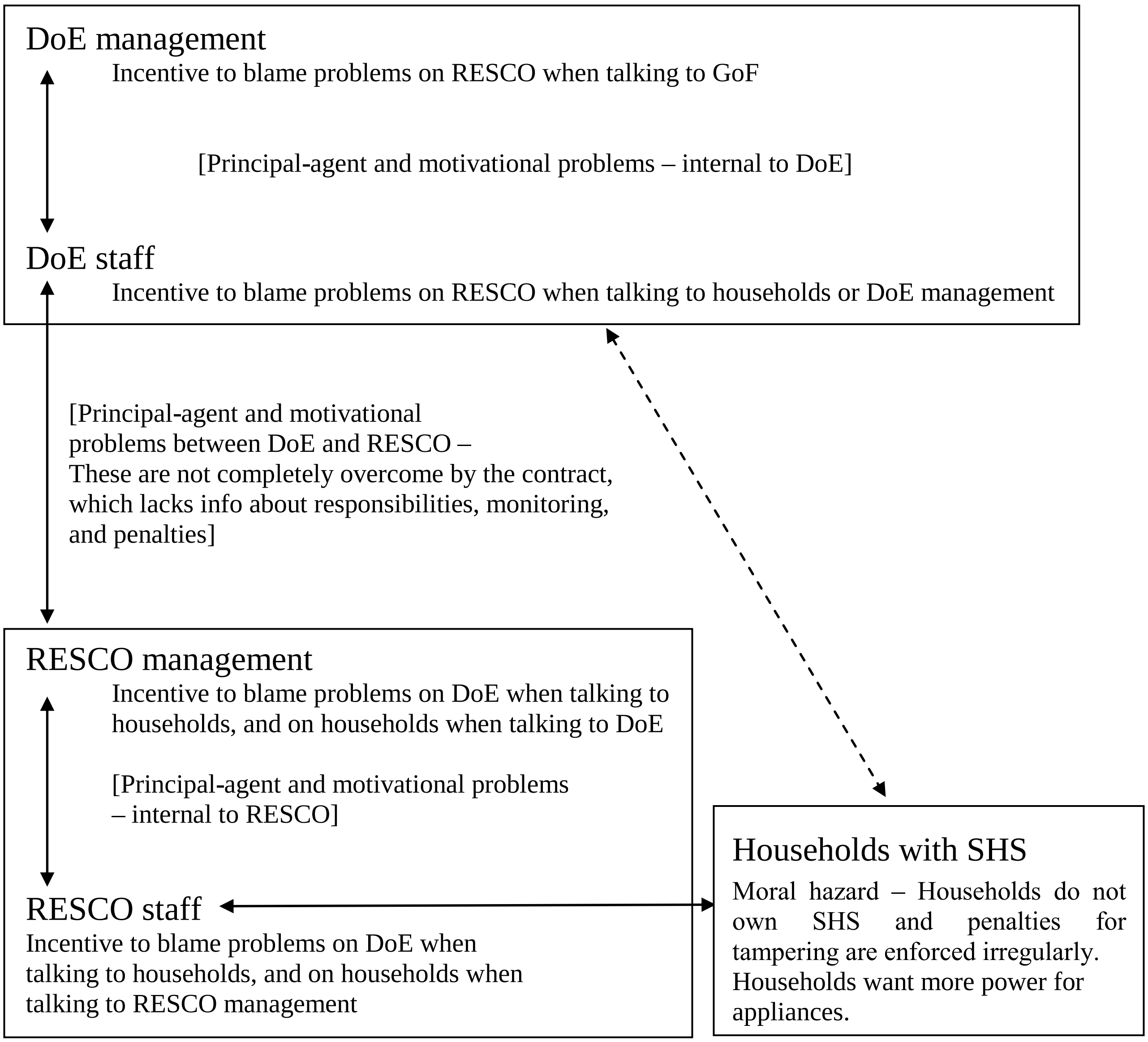
Moral hazard problems also affect the *RESCO Program*, although not to the extent of the principal-agent and motivational problems already mentioned. Moral hazard problems occur where an individual is protected against loss once a contract has been entered into (Ostrom, et al. 2001). Under the RESCO model, users are the most likely group to face moral hazard problems, as SHS remain the property of the Department of Energy. Households are less likely to care for systems that are not owned by them. This means they may tamper with SHS, shortening their lifespan. In interviews with both RESCO and Department of Energy staff, the tampering with SHS by households was cited as an important reason for system failures (Interviews with Department of Energy and RESCO staff, November and December 2009).

6.3.4 Patterns of Interaction and Incentives

The *RESCO Program* has failed to provide adequate maintenance to SHS installed under the program. This was shown in chapter five to have resulted in long power outages caused by technical problems, with surveyed households suffering an average of 234 days of system failure in a two-year period over 2008-09. Households with SHS were also unsatisfied with maintenance provided under the *RESCO Program*, with only six households satisfied out of the 40 that were surveyed. Dissatisfaction coupled with moral hazard problems resulted in frequent tampering with SHS, commonly through the use of car batteries where SHS batteries had failed. In many cases this shortened the life of SHS and contributed to poor performance.

Incentives generated by the *RESCO Program* can explain this poor maintenance. At a superficial level, the RESCO appears to have as its primary incentive meeting its contractual obligations (providing basic maintenance) at the lowest possible cost (to maximise profit). The Department of Energy has an incentive to ensure the RESCO provides basic maintenance, while minimising the level of monitoring required of it, and households have an incentive to pay their FJ$14 fee and ensure that their SHS function correctly. This superficial analysis however does not account for a range of complicating factors. Importantly, it does not distinguish between staff and management within the RESCO and the Department of Energy, or account for their different incentives. Nor does it look at information asymmetries within and between these organisations, which cause a series of principal-agent and motivational problems. The presence of principal-agent and motivational problems at several levels in the *RESCO Program* are shown in figure 6.3.4a.

Figure 6.3.4a. Information Asymmetries in the *RESCO Program*



RESCO Incentives

A key failure of the RESCO model put in place in Fiji is that it does not link payments to the RESCO to the performance of SHS. As a result, strong monitoring systems are needed in order to overcome principal-agent issues and ensure that the RESCO has incentives to perform adequate maintenance. Existing monitoring systems are inadequate, and focus on household visits rather than whether SHS are functioning. This gives the RESCO incentives to ensure household SHS are inspected, but not to ensure that they are operational. The records and discussions with households indicate that these incentives have affected RESCO activities. RESCO technicians did visit most households every second month in 2008-09, but visits were commonly short and major repairs of non-functional SHS were often avoided (technicians claimed that this was the result of late delivery of components by the Department, which is an issue discussed below).

The incentives of RESCO technicians were also affected by motivational problems. Information asymmetries between RESCO management and technicians were severe. RESCO technicians therefore had incentives to pass on information to RESCO management that was favourable to them, but not necessarily accurate. Technicians also had incentives to avoid work or perform maintenance at a sub-standard level, as they do not receive payment for the number of houses they service or for the standard of service.

Incentives of Department of Energy Staff

Motivational problems also affect employees in the Department of Energy and reduce incentives. Interviews with RESCO management indicate that it was unhappy with the performance of the Department in several areas, including SHS component purchasing, RESCO payment and the renewal of the RESCO's contract. Employees in the Department are responsible for all these roles, although purchasing SHS components also needs to be processed by the Major Tenders Board, which Department of Energy staff indicated was a bureaucratic process. Employees face motivational problems in each of these tasks. This is compounded by features of the Department mentioned earlier, including: understaffing, high staff turnover, and the mixed responsibilities of staff (Interviews with Department of Energy staff, 2009). It is therefore likely that poor performance of the Department in its tasks, and especially delays in component replacement, have been partly a result of motivational problems in the Department.

Incentives of Households

Tampering with SHS by households has been one reason for the poor performance of SHS under the *RESCO Program*, as indicated previously. The response of the Department is to authorise RESCO technicians to penalise households that have tampered with SHS according to rules that are included in the contract signed by households when SHS are installed. However, as with maintenance by the RESCO, it is difficult to monitor tampering of systems because of the remoteness of those households. Irregular penalisation of households by RESCO technicians has also lessened the disincentive for households in tampering with SHS.

Lessons from previous solar projects implemented in the Fiji Islands are instructive here. Experience strongly suggest that both tampering and fee payment by households depend in large part on customer satisfaction (Wade 2003). Customer satisfaction has been poor under the RESCO model, due to maintenance problems leading to SHS failure, and a “one size fits all” approach that has led wealthier households to tamper with SHS in order to power appliances (Interviews in Vunivao, December 2009). The most effective way to address tampering is therefore likely to involve improving customer satisfaction by providing better maintenance and offering various SHS sizes under the *RESCO Program*.

6.3.5 Outcomes

The *RESCO Program* faces a number of problems at the operational level that have affected the provision of maintenance. Tampering has affected the lifespan of some systems, while delays in the purchase of SHS components have resulted in SHS that are non-functional over a long period of time. Most important however is the failure of the *RESCO Program* to align the incentives of stakeholders in such a way that each benefits from the provision of maintenance and the functionality of SHS. If there was voluntary trust between the stakeholders or if information were perfect this would not affect maintenance provided by the RESCO. This is not the case. Information asymmetries create principal-agent and motivational problems between and within the RESCO and the Department of Energy.

Contractual agreements to some extent overcome these information asymmetries, establishing a degree of enforceable trust. Employment contracts and internal monitoring measures put in place in the RESCO and the Department provide incentives for staff to complete work, while contractual obligations and monitoring of the RESCO have ensured that technicians visit households every second month. However such measures can never be perfect. Flaws in the contract between the Department of Energy and the RESCO are one of the key reasons that maintenance to date has been unsatisfactory, with unclear penalties, responsibilities and monitoring procedures. The failure to overcome information asymmetries has led to a model where stakeholders can avoid responsibility for unsatisfactory maintenance, instead blaming other groups. This in turn has resulted in conflict, further eroding voluntary trust between the Department and the RESCO. The end result for the RESCO in question was the termination of its contract in November 2009 by the Department of Energy, which shortly after awarded the contract to another company.

The move to terminate the contract of the previous RESCO reflected Department of Energy thinking that the RESCO itself was the main cause of maintenance problems, not the *RESCO Program*. Subsequently the Department has moved ahead with plans to extend the model to other islands in Fiji, in response to strong demand for SHS in those areas. This study urges for caution in doing this. The failure of the *RESCO Program* cannot be attributed solely to the company responsible for maintenance. Rather, it is the result of an institutional framework that does not adequately consider or appropriately align the incentives of stakeholders. Anecdotal evidence from the Department of Energy in July 2010 supports this view, with the performance of the new contractor also said to have been substandard. Alignment of the incentives generated by the *RESCO Program* is necessary to ensure that future installations of SHS do not suffer from the same problems, and should occur before the program is expanded.

This study suggests that some relatively minor changes have the potential to address the incentive problem and generally improve the *RESCO Program*. These include:

- Making the RESCO’s revenue dependent on whether SHS are working (as argued for by the original donor proposal), possibly by having the RESCO collect money directly from households.

- Ensuring SHS spare part delivery is timely, which might occur if orders were administered by the RESCO, provided there was adequate financial oversight of these purchases.
- Establishing an improved monitoring framework to address customer complaints and ensure difficult SHS repairs are conducted by the RESCO.
- Moving away from the "one size fits all" model and offering applicants the choice of various SHS sizes for different prices.

These relatively minor changes could ensure that the RESCO model aligns stakeholder incentives with the maintenance of SHS. For any of them to be successful however, the Department of Energy would need to be resourced adequately for the role, both in terms of its staff numbers and budget. These issues are discussed in more detail in section 6.5.

6.4 The Policy Level: Diesel-Based Rural Electrification under the *Rural Electrification Policy*

Policies governing rural electrification have a significant impact on the performance of off-grid electricity generation through their establishment (or lack of establishment) of operation and maintenance arrangements. Rural electrification policies are also a key determinant of choice of technology and the rate of access to electricity in rural areas. The *Rural Electrification Policy* gives villages the responsibility for purchasing fuel and providing maintenance to diesel generators, with village social arrangements used to perform these activities. The result has been poor performance of village generators, which often suffer power outages due to technical problems and shortages of fuel.

6.4.1 Action Arena: Actors and the Action Situation

The establishment of policies for rural electrification can be understood as occurring in an "action arena", in the same way as can maintenance. The action arena examined below involves two action situations: the development of rural electrification policy and its implementation. A range of actors are involved. The Department of Energy is the primary agent responsible for drafting rural electrification policy, which it does with the assistance and advice of consultants; while cabinet members and the Minister for Works, Transport and Public Utilities approves rural electrification policy for it to take effect. Implementation of rural electrification policy is the primary responsibility of the Department of Energy, but this occurs within the constraints of public service rules put in place by the Ministry of Finance and the Public Service Commission, and a budget determined by cabinet on the advice of the Ministries of Finance and National Planning.

6.4.2 Influences on the Action Arena (or Context): Physical Conditions, Attributes of Community and Rules-in-Use

In many areas of Fiji, off-grid provision of electricity is more cost effective than extension of the electricity grid. At the same time, the remoteness of many communities creates difficulties in the provision of services, with collection of fees, provision of maintenance, and the supply of fuel a challenge in remote areas.

Government structures and resources also have an impact.[164] The rural electrification budget is determined each year by cabinet and therefore influenced by the spending priorities of government and the fiscal resources that are available. Until recently, only small amounts of money were provided to the Department for rural electrification. These figures have grown in recent years; however the amounts have varied considerably from year to year, as shown in table 6.4.1a.

[164] Chapter five described how the FEA has a disincentive to expand electricity grids to rural areas as a result of the uniform national tariff for electricity (which means it makes a loss for electricity sold in rural areas).

Table 6.4.1a. Rural Electrification (RE) Budget, 1990-2010

Year	Govt funding for RE (FJ$ million)	Aid funds for RE (FJ$ million)	Total funding for RE (FJ$ million)
1990	0.3	0.7	1
1991	0.3	0.5	0.8
1992	0.3	0	0.3
1993	0.2	3.7	3.9
1994	1	0.7	1.7
1995	1	0	1
1996	1*	1	2 (6 incl. grid ext)
1997	1	0	1
1998	3.1	0.3	3.4
1999	6.5	2**	8.5
2000	1.5	n/a	
2001	3	n/a	
2002	5	n/a	
2003	6	n/a	
2004	6	n/a	
2005	6	0	6
2006	6.2	0	6.2
2007	3.9***	0	3.9
2008	6	8.3	14.3
2009	17****	1	18
2010	6	n/a	

n/a – Data not available

*In addition, the Government provided a grid extension and infrastructure development grant of FJ$6 million over three years from 1996 – 1999

**The Chinese Government provided FJ$1 for rural electrification projects. The French Government provided FJ$1 million for a solar-based rural electrification scheme

***FJ$4.347 million provided in the budget, only FJ$3.9 million of which was spent

****Budget originally provided for FJ$9.795 million (FJ$2 million of which was for infrastructure development of the electricity grid), with the remainder being provided towards the end of the year as part of a policy announcement about rural electrification

Source: Department of Energy (2000), Government of Fiji Budget Estimates (2006, 2007, 2008) , SOPAC (2003), Interviews with Department of Energy Staff (2009 and 2010), Department of Energy List

The Department of Energy, a relatively small unit within the Ministry for Public Utilities, Transport and Energy, has very little power in influencing budget allocations for rural electrification when compared to central ministries that advise the government on a frequent basis. The final decision about the rural electrification budget and the Department of Energy's core budget resides with cabinet. In practice however, it is likely that the Ministries of Finance and National Planning wield considerable influence with their advice to government.

Fiji Public Service rules also affect rural electrification by determining the number of staff available to the Department of Energy. The Public Service Commission approves all submissions for new staff in the Fiji Public Service, including in the Department of Energy (Interviews with Department of Energy management and former management, July and November 2009). This has led to chronic understaffing at the Department of Energy for many years. It took the Public Service Commission 10 years to approve the hiring of staff for a Rural Electrification Unit, even after its establishment had been approved by cabinet as part of the *Rural Electrification Policy*. Public service rules also establish the process through which rural electrification occurs. Installation of new systems under the rural electrification policy is governed by tender rules that apply across the public service. These dictate that all projects with a value above FJ$50,000 must be placed through a tender that is administered by the Major Tenders Board. Tendering through this process follows strict procedures and can take some time, leading to delays in the installation of systems (Interview with Department of Energy staff, November 2009).

6.4.3 Patterns of Interaction and Incentives

Rural electrification policy is largely determined by cabinet with advice from central ministries. Although the Department of Energy provides advice to the government and is responsible for implementation of rural electrification, it is in practice subordinate to the central ministries and must abide by public service rules determined centrally. It also depends on funding that is determined by cabinet with advice from central ministries. This makes the incentives and priorities of Cabinet members and central ministries important for a study of rural electrification.

Rural Electrification: A Low Priority

The ability of agencies like the Public Service Commission and Major Tenders Board to negatively affect rural electrification projects by placing burdensome procedures on the Department of Energy reflects the low priority accorded to these activities. Historical levels of funding also suggest that rural electrification is generally a low priority for both cabinet members and central ministries. In part, this reflects the priorities of rural areas themselves. Transport links such as roads and shipping services offer income-earning opportunities and are more important than electricity provision for most rural areas, where electricity is considered a luxury and provides mainly lighting services (Department of Energy 2006b). Similar trade-offs also exist in other developing countries (Pearce and Webb 1987).

Urban bias is also likely to lessen the priority given to rural electrification. Infrastructure spending favours urban areas in most developing countries, and this appears to also apply in Fiji. The most visible demonstration of this is spending on roads. The uniform tariff rate applied by the FEA similarly favours areas that are already connected to the grid over those that are not connected, as it does not provide the FEA with an incentive to extend the electricity grid. Chapter four described how the tariff rate is determined by the cost of generation; no attempt is made to charge consumers a higher rate in order to fund grid extensions.

The result of the low priority given to rural electrification is twofold. First, funding provided for rural electrification has been relatively low, and has risen only in recent years. The *Rural Electrification Policy* of 1993 advocated funding of FJ$6 million per year (in 1993 dollars) for rural electrification, however table 6.4.1a shows that these levels have only been achieved in 1999 and possibly since 2003 (depending on aid flows). Prior to 1998, government funding failed to rise above FJ$1 million.

The second result of the low priority given to rural electrification is delays in the implementation of rural electrification policy.[165] This has had particularly adverse consequences for the Department of Energy, which has not acquired the staff required to administer the policy. The *Rural Electrification Policy* approved by cabinet in 1993 advocated the establishment of the Rural Electrification Unit that would operate alongside the Department of Energy and would administer applications for rural electrification. This unit, while established in name, had still not been provided with staff in 2003 (10 years after the 1993 cabinet decision). During that time the Department of Energy had to use its existing resources to process applications for rural electrification (Matakiviti and Pham 2003). Limited resources contributed to delays in installations.

The Prioritisation of Short Term Political Gain over Long Term Sustainability

Where governments have shown interest in rural electrification, they have done so at least in part in order to gain political capital, or public support. This is consistent with political economy arguments made more broadly about government funded infrastructure development throughout the world. Similar arguments are used by Ostrom et al. (1993) to explain the frequent prioritisation of new infrastructure projects over maintenance of existing projects, and the resulting short life span of much infrastructure in developing countries (Prasad and Narayan (2008) make a similar claim for infrastructure maintenance in Fiji, claiming there is a FJ$3.42 billion "infrastructure deficit" dating back 20 years).

The presence of a non-elected military government does not necessarily change things. In Fiji, government concern about public opinion appears equally strong in the case of both elected and unelected governments. Recently, this has been shown by public relations campaigns and attempts to limit negative reporting about the government in the media. In this context, government interest in rural electrification can be understood in terms of "announcables", or good news stories. New rural electrification projects frequently appear

[165] Low levels of funding have slowed the rate of rural electrification in Fiji, and have led to delays in the installation of diesel generators in villages. Department of Energy staff stated that once a community makes its contribution to the capital cost of generator, it often must wait for over a year before the generator is installed (although this is also influenced by delays in processing and in the tender process that occurs with each installation).

in the local press and in government press releases, increasing public support for government (Government of Fiji 2011).

The other implication of concern for short term political returns is that the long term sustainability of rural electrification projects is not considered. In Fiji, this partially explains the many energy-related pilot projects that have been established (commonly with donor funding) but have later failed as a result of a lack of support from government.[166] Examples include various solar projects in the 1980s and 1990s, biofuel projects in Welagi, Taveuni and Lomaloma, Vanua Balavu, and the Nabouwalu hybrid system.

The Nabouwalu hybrid system is the biggest of the projects mentioned. It involved a hybrid solar-wind and diesel system that was designed to power the government station in Nabouwalu, at a cost over FJ$1 million, the majority of which (FJ$800,000) was paid by the Government of Japan. The project was greeted enthusiastically by Government officials when installed in 1998. After the 2000 coup however the Public Works Department was reorganised and staff trained to operate the system moved on to other jobs. The solar and wind components of the system fell into disuse as a result (Vega 2005; Interviews with Department of Energy, November and December 2009). Figure 6.4.3a provides an illustration of a disused solar panel that formed part of the system.[167]

[166] Another explanation relates to lack of "ownership" of energy projects by government, which is discussed in the following section.

[167] The perspective of the Department of Energy technicians that travelled to Bua province in November 2009 is interesting in this respect. They said that the failure of the project was the result of the landowners of the site where it was installed "not being treated right". The proper procedures were not followed in acquiring the land, with no *sevusevu* offered to the *mataqali* that own the land. As a result, the project was inevitably going to go wrong. As stated by one of the technicians: "It happens all the time. People build stuff on someone else's land, and that person will get sick or something bad will happen to them or their family" (Interviews with Department of Energy staff, November 2009).

Figure 6.4.3a Image of disused solar panels that form part of the Nabouwalu hybrid system

The prioritisation of short term political outcomes over long term sustainability has also affected the design and funding of rural electrification in Fiji. The *Rural Electrification Policy* of 1993 provides three years of free maintenance to communities when a generator is installed. No support is provided to communities beyond the initial three-year period. The evidence suggests that this has resulted in significant periods where power from installed generators (and other technologies) is not available (Department of Energy 2006b). In fact, a Review of the *Rural Electrification Policy* conducted in 2003 argued that the three years free maintenance should be abolished, as it served only to increase the dependence of communities on the Department while providing no subsequent support in the maintenance or operation of the generator (Matakiviti and Pham 2003). The advice was ignored. The *Rural Electrification Policy* also advocated the establishment of a sustainability fund by each village to set aside money regularly for maintenance of the diesel generator. This recommendation has not been implemented (Matakiviti and Pham 2003; Interviews with Department of Energy, November 2009).

Interest in rural electrification has been particularly strong under the interim military government. The interim government has increased the resources given to the Department of Energy for rural electrification, which has boosted the number of rural households that gain access to electricity each year. The increase however has not been stable, as shown in table 6.4.1a. Department of Energy management were not aware of the reasons for changes in funding (Interviews with Department of Energy management, November and December 2009). A possible explanation again relates to government concern for short term political gain. High levels of funding for rural electrification were announced as a boon to rural areas as part of a broader government strategy to promote rural development (Government of Fiji 2007b). This served to increase the political capital of leaders. Funding cuts to rural electrification contained in the 2011 Budget received little publicity however, and therefore did not significantly affect the political standing of leaders.

The interim government has also raised the level of the government subsidy for rural electrification from 90 to 95 per cent of the total capital cost of each project. Like the increase in the rural electrification budget, this does nothing to overcome problems with the sustainability of installed rural electrification projects. Quite the opposite is true: households that cannot afford to pay 90 per cent of the capital cost of a project are unlikely to be able to afford future maintenance fees. Increasing the subsidy is therefore likely to be bad for sustainability. The move instead appears to be primarily motivated by political reasons, and is further evidence of government prioritisation of short term political gain over long term sustainability of rural electrification projects in Fiji.

6.4.4 Outcomes

Cabinet and the central ministries heavily influence the establishment and implementation of the *Rural Electrification Policy*. The Department of Energy's role in administering the policy occurs within the parameters set by these groups, which allocate funding for rural electrification, determine the level of available resources, and establish the public service rules that the Department must follow. Low and variable levels of funding suggest that rural electrification has been a low priority for successive governments and central ministries. Administration of rural electrification funding has been constrained by inflexible public service rules and a lack of accompanying funds or staff for the Department of Energy (or the Rural Electrification Unit). A general disregard for the sustainability of rural electrification projects suggests that what interest governments have shown in rural electrification has been politically motivated.

The design of the *Rural Electrification Policy* has likewise failed to ensure the long term sustainability of installed systems, placing the responsibility for system sustainability on rural villages. The establishment of a sustainability fund has not been implemented, while the three-year grace period where maintenance is provided by the Department has been found to be detrimental rather than beneficial for sustainability (Matakiviti and Pham 2003). The result has been poor maintenance of diesel generators and frequent power outages.

6.5 The Policy Level: Solar-Based Rural Electrification under the *RESCO Program*

This section is concerned with the policy environment for solar-based rural electrification under the *RESCO Program*. Section 6.3 outlined how maintenance provided by the RESCO has been inadequate, and performance of SHS has as a result been poor, due primarily to incentive issues. Government implementation of the *RESCO Program* has also failed to resource the Department of Energy so that it can monitor the activities of the RESCO, and has led to delays in the purchase of replacement SHS components, which must be made through the Major Tenders Board.

6.5.1 Action Arena: Actors and the Action Situation

The action arena analysed here includes the design of the *RESCO Program* (beginning in 1998) and its subsequent implementation at the policy level. The central actor is the Department of Energy, which is responsible for the implementation of the program and was involved in its design. Also important are donor funds, such as those provided by the Global Environment Facility (GEF), and contractors, such as staff at the Pacific International Center for High Technology Research (PICHTR). Both GEF and PICHTR staff played a key role in the design of the *RESCO Program*. Cabinet and the Minister for Works, Transport and Public Utilities, also have a role in approving rural electrification policy, and influence the implementation of the program through control of funding. Lastly, public service agencies such as the Ministry of Finance and Ministry of National Planning, Public Service Commission and the Major Tenders Board, influence the way the Department of Energy implements the *RESCO Program*, through control over Department of Energy staffing, public service rules, and advice to government on funding.

6.5.2 Influences on the Action Arena (or Context): Physical Conditions, Attributes of Community and Rules-in-Use

The *RESCO Program* was in large part developed to address previous barriers to SHS in Fiji, by removing the high upfront capital costs associated with SHS (and charging customers according to system life-cycle costs), and establishing institutional arrangements that would ensure that good maintenance was provided. It also sought to remove the maintenance role from government, which generally has a poor history of service delivery in the Pacific islands, and had failed to provide adequate maintenance in previous solar electrification schemes in Fiji (Liebenthal, et al. 1994; Wade 2003; Wade, et al. 2006). In addition, it was hoped that having the government purchase the SHS equipment would ensure that their overall cost was lowered (GEF-UNDP 2002; Vega 2003; Wade, et al. 2006).

Government structures and funding arrangements

Government structures and funding arrangements have affected the implementation of the *RESCO Program* in similar ways to the 1993 *Rural Electrification Policy*. Funding for SHS installations under the *RESCO Program* comes from the same body of money used for rural electrification under the *Rural Electrification Policy*. In effect, cabinet provides a set amount of money for rural electrification to the Department of Energy on an annual basis. The Department of Energy then decides whether that money is used for SHS installations under the *RESCO Program*, or on other forms of rural electrification under the *Rural Electrification Policy* (commonly FEA extensions or the installation of diesel generators).

The Department bases its decision on the preferences of applicants for rural electrification, who specify a preferred technology in their application. The result is that SHS installations under the *RESCO Program* are subject to the same budgetary uncertainties and instability, as well as low levels of funding, as are rural electrification projects under the *Rural Electrification Policy*. This has led to a big backlog of paid requests for SHS (Interviews with Department of Energy, July 2009).

At the same time, the resources available to the Department of Energy for administration of the *RESCO Program* are determined by cabinet, based on recommendations provided by the Ministry of Finance. The Department of Energy has never formally been provided with funding for the administration of the *RESCO Program*. Instead, payments to the RESCO are provided to the Department under its annual budget (for remittance to the RESCO). This allows the Department to cover its administration costs associated with the *RESCO Program* (such as travel for RESCO monitoring) by using a component of the FJ$13.50 received from households with SHS (Interviews with Department of Energy, November and December 2009). More problematic is the fact that the Department of Energy has never been provided with staff to administer the *RESCO Program*. Staffing levels in the Department of Energy are determined by the Public Service Commission, which approves applications for new staff (as detailed in the previous section). Applications made by the Department for additional staff to administer the *RESCO Program* have not been successful, meaning that the Department must draw on its core staff, as well as staff from the Rural Electrification Unit (which is not responsible for the *RESCO Program*) to administer the program.[168] This means that Department of Energy staff members who administer the *RESCO Program* do so in addition to their other responsibilities (Interviews with Department of Energy, November and December 2009).

Public service rules also require that all installations, maintenance contracts, and purchases of SHS components over FJ$50,000 in value are made through the Major Tenders Board. This has resulted in delays in the supply to the RESCO of SHS spare parts, which are required to repair non-operational SHS (Interviews with RESCO and Department of Energy, November and December 2009). Strict rules surrounding tender applications have also resulted in periods where no organisation is contracted to provide maintenance to SHS. For example, in 2007 the tender application made by RES Limited (the RESCO contractor from 2005 to 2010) was delivered several hours after the deadline.[169] The Major Tenders Board refused to accept it, despite there being no other applicants. The Department of Energy had to subsequently go through the bureaucratic process of producing another tender, which took several months. During that period, from March 2007 to July 2007, no company was contracted to perform maintenance on SHS (Interviews with Krishn Raj, November 2009).

6.5.3 Patterns of Interaction

Solar-Based Rural Electrification: A Low Priority

Part of the problem with the *RESCO Program* now in place is that it differs in key areas from the model that was recommended by donors. In the original proposal, the RESCO was to lease the SHS from the government for a fee based on recovery of the non-subsidised portion of the capital cost of the SHS; be responsible for collecting money from users

[168] In recent years this can be explained by a public service wide recruitment freeze put in place by the interim military government in 2007 (Interview with former Department of Energy management, November 2009).
[169] Mr Krishn Raj, the manager and owner of RES Limited, stated that the original application must have been lost in the mail. Because a physical copy was required, he subsequently flew to Suva from his base in Labasa in order to deliver the application in person on the day it was due.

(whether through a pre-payment meter as currently used, or through physical collection); pay a fixed amount for each SHS maintained into a Component Replacement Fund, which would be used by the Department of Energy to purchase replacement SHS components; and select the equipment used in the SHS, as this would have a direct bearing on the RESCO's profitability. The Department of Energy would still purchase spare parts (using money from the Component Replacement Fund) as this would allow for economies of scale, making the equipment cheaper (GEF-UNDP 2002; Vega 2003).

Under that framework, the RESCO had a strong incentive to ensure that SHS worked. Where they did not, households would not pay the FJ$14 fee and the RESCO would lose that revenue. Furthermore, the RESCO would still be required to deposit money into the Component Replacement Fund controlled by the Department of Energy. System failures therefore resulted in financial losses for the RESCO.

The *RESCO Program* now in place has no such incentive structure. Successive governments, rather than establish the institutional arrangements recommended by donors, have instead kept in place the temporary RESCO framework that was set up for the small pilot program. The RESCO under that structure receives payment regardless of whether or not SHS are functioning, and therefore has no direct financial incentive to ensure that SHS remain functional (as described in section 6.3).

A lack of interest in the *RESCO Program* by the Government of Fiji can explain why institutional arrangements established for the pilot program remain. This is a view shared by some of the individuals involved in establishing the RESCO model (Wade, et al. 2006). The government's failure to pass the *Renewable Energy Based Rural Electrification Bill* further demonstrates that successive governments have considered the program a low priority. That legislation would have provided a legal foundation for the *RESCO Program* and reflected the institutional framework originally proposed by donors. The low prioritisation of the *RESCO Program* can also explain resourcing and administrative constraints that have affected the program.

The reasons for the lack of government interest in the *RESCO Program* are several. One explanation relates to ownership. Ownership issues are frequently observed in aid-recipient relations, where aid is provided to recipients in the expectation they will act in a certain way, only for this not to occur (Ostrom, et al. 2001; Ostrom, et al. 1993). In the case of the *RESCO Program*, the original model proposed by the aid donor was externally designed, with limited input from the Department of Energy (personnel that were involved in its design subsequently left the Department). Other Government of Fiji stakeholders, such as cabinet and the powerful Ministry of Finance and National Planning, were not involved in its design. This meant no ownership of the program among these organisations.

Frequent changes in government are likely to also have affected ownership. There have been five changes in government in Fiji (including two coups) since 1998, when the *RESCO Program* was designed. As a result, while successive governments have had political incentives to accept donor aid in the form of SHS that were installed in Vanua Levu, they have not had corresponding incentives to establish the institutional structures advocated by donor groups.

Mismanagement of Economic Reform

It is worth noting that the capacity of the Department of Energy to administer the RESCO scheme with its current resources was highlighted as an issue by a consultant in the early stages of the *RESCO Program* (Saupin 2003). This raises a more general question about the need for government involvement in administering a program where maintenance is provided by the private sector. The move towards private sector provision of maintenance was motivated in part by the wish to transfer the role away from government (GEF-UNDP 2002; Wade 2003). Underlying this were broader economic arguments about the efficiency of private sector as opposed to public sector provision of services, including infrastructure services (Department of Public Enterprises 1998).

In Fiji, not enough attention was paid during this period to the important role that government would need to play to ensure these reforms were a success. This resulted in the failure and eventual reversal of several reforms, and contributed to the lack of continuity in the reform process (as outlined in chapter four) (Appana 2003; McMaster 2001). Enactment of the requisite legislation in the form of the *Public Enterprise Act 1996* was not sufficient for reform. As Sarker and Pathak argue, “formal institutional reforms are not enough to bring about necessary changes. It is the organizational capability that will put into effect the changes made” (2003: 70). This was lacking in the case of Fiji.

The implication of this for the *RESCO Program* has been twofold. First, there has not been enough attention paid to the role of the Department of Energy in monitoring the RESCO and sourcing spare parts, for which a budget and staff are needed. Second, the need to ensure incentive compatibility was never addressed.[170] This was unfortunate, as designing the *RESCO Program* so that stakeholder incentives were aligned with ensuring SHS sustainability could have significantly reduced the level of monitoring of RESCO activities required under the program. The result is that the *RESCO Program* now in place requires extensive monitoring by the Department of Energy, which has not been given sufficient resources to perform the role.

The Prioritisation of Short Term Political Gain over Long Term Sustainability

Government prioritisation of short term political gains from rural electrification can also explain some of the features of the *RESCO Program*. In the original proposal for the *RESCO Program*, the tariff charged to users was to be set to cover all maintenance costs, profits for the RESCO, and the 5 per cent (10 per cent at the time) capital cost borne by the household. The tariff would therefore remain flexible, and would be negotiated once every two years for each service area by the RESCO and community representatives, with a final decision on the tariff level being made by the Department of Energy with input from the Commerce Commission (which sets tariffs for Fiji’s electricity grid). However the tariff review that was to have occurred under the original proposal has never taken place. The tariff of FJ$14 now charged to households is the same tariff that was put in place in 2000 when the pilot program began.

The failure to increase the FJ$14 tariff despite inflation and the devaluation of the Fiji dollar is likely to reflect government concern that a tariff increase would be politically unpopular. The low tariff is not necessary for affordability. Fieldwork results presented in

[170] Incentive compatibility involves ensuring that stakeholders have incentives to share private information with other stakeholders.

chapter five found that the majority of households were willing to pay a higher tariff for SHS, so long as they remained operational. These findings are supported by surveys in 2003 and 2005, which found that on average, un-electrified households in rural areas spent about FJ$21 on kerosene, benzine and batteries for lighting; more than the FJ$14 currently charged for a SHS (Department of Energy 2006b; Vega 2003). The low tariff raises questions about the sustainability of the *RESCO Program*, should government subsidisation of the program, which has not been made explicit, cease.

The expansion of the *RESCO Program* to areas outside of Vanua Levu in 2010 can also be explained by political motives. This expansion responds to demand for SHS in other areas of Fiji, which Department of Energy staff indicated has also been considerable in recent years (Interviews with Department of Energy staff, November and December 2009). It is nevertheless puzzling, given the serious problems with maintenance being experienced under the *RESCO Program*. These problems are known to government, as officials in Labasa stated that the problems had been raised in person with cabinet by the Commissioner Northern, Col. Inia Seruiratu, in 2009. The most likely explanation for the expansion under the circumstances is that it is occurring for political reasons, in response to demand for solar systems among communities outside of Vanua Levu. It also seems clear that the government is paying (and has paid) more attention to new SHS projects than to the maintenance of existing ones.

6.5.4 Outcomes

The implementation of the *RESCO Program* in its current form is heavily influenced by government structures and funding, which are determined by cabinet, the Minister for Works, Transport and Public Utilities, and central ministries. Implementation of the program to date has demonstrated a lack of interest in the program by those entities, and a prioritisation of short term political gains over long term sustainability of installed solar systems. This can be partly explained as an ownership issue, and is the result of both frequent government change, and a failure to engage the central ministries in the design of the *RESCO Program*.

6.6 Conclusion

This chapter has analysed the impact of institutional arrangements for rural electrification on the security of off-grid electricity supplied by both diesel and solar-power systems. It has also assessed the formation and implementation of rural electrification policy, and its impact on energy security.

For diesel systems, the most important reason for power outages is the inability of communities to collect sufficient funds for fuel purchases through village *solis*. This is the result of the non-excludability of electricity provision from village diesel generators, which creates an incentive for households to "free-ride". Gift-exchange relations under the *kerekere* system to some degree overcome this problem, ensuring that sufficient funds are collected the majority of the time. However this does not always occur. The failure to collect sufficient funds results in frequent changes in collection methods, which have come to form part of the political cycle within villages. Social relations also affect maintenance of village generators.

For solar systems, technical problems have adversely affected the security of solar-based electricity supply as a result of inadequate maintenance. The *RESCO Program* lacks both voluntary and enforceable trust, and does not align the incentives of stakeholders with the goal of providing maintenance. Instead, flawed and insufficient monitoring by the Department of Energy has generated perverse incentives for the RESCO, which is rewarded even where solar systems are not functional. Information asymmetries in the *RESCO Program* have also resulted in conflict between the RESCO and the Department of Energy, further eroding trust between the organisations.

Many of the problems that cause insecurity in rural electricity supply are the result of policy design and implementation. This is especially true for the *RESCO Program*, which has not been implemented as originally designed. The result has been that the incentives of the RESCO are not aligned with those of the program, and the Department of Energy is not adequately resourced for its monitoring role. Reasons for this include low levels of ownership of the *RESCO Program* among successive cabinets and central ministries, as well as low prioritisation of rural electrification projects and general disregard for their sustainability.

Diesel-based rural electrification has also been affected by policy design and implementation. Funding for rural electrification has been below levels recommended under the *Rural Electrification Policy* for over a decade, and although it has been higher in recent years, it is highly unstable. Resourcing of the Department of Energy has also been inadequate, with the government taking over ten years to establish the Rural Electrification Unit. Sustainability issues have also not been adequately addressed by the *Rural Electrification Policy*, with the few measures it does include to improve sustainability of installed systems not having been implemented. This has adversely affected the sustainability of off-grid electrification systems.

Chapter 7

Addressing Barriers to Renewable Technology Investment: Policy Options

This chapter explores policy implications identified in previous chapters. The focus is on options available to the Fiji Government in addressing barriers to renewable technology investment, which has been shown by this dissertation to improve energy security in both off-grid areas and the electricity grid. The chapter discusses financing arrangements in some detail, given the detrimental impact a lack of finance has had on investment in the power grid. The impact of political instability and other barriers to renewable technology investment are also explored. The chapter proceeds to examine rural electrification policy. Ambitious electrification targets established by the Fiji Government are found to be appropriate, but require additional resources and a number of policy changes if they are to be achieved.

7.1 Introduction

A number of policy implications have been identified in the research findings already outlined. This chapter explores these policy implications in more detail. In doing so, it addresses the following questions:

Is government policy regarding renewable technologies appropriate? Should more be done by government to facilitate and overcome barriers to renewable technology investment in Fiji? What would this involve?

The chapter is divided into two parts. Policy implications for the power grid are examined in part 7.2. Policy implications relevant to rural electrification are examined in part 7.3. Section 7.2.1 revisits the findings of the economic modelling and the analysis of electricity sector regulation presented in chapters three and four. The portfolio analysis suggested that investment in low-cost, low-risk renewable technologies is desirable from an economic standpoint, resulting in lower generation costs and financial risk for the electricity grid. The analysis of regulatory arrangements in the electricity sector demonstrated that power sector reform is encouraging such investment, although a number of barriers remain.

Limited access to financing is the biggest barrier to power sector investment among Independent Power Producers (IPPs), and is closely linked to external perceptions of political uncertainty in Fiji. Section 7.2.2 examines potential financing options for investments in renewable technologies. It looks at the impact of regulatory changes on financing of FEA and IPP investments, and potential sources of external financing such as donor support and carbon funds. Section 7.2.3 examines policies that could address other barriers to investment in renewable technologies. These include measures that could facilitate access to renewable energy resources; and policies designed to address regulatory failures associated with energy efficiency technologies, and upfront exploration and research costs.

Section 7.3.1 reviews analysis of rural electrification policies. Maintenance issues identified in chapters five and six need to be addressed for the successful expansion of rural electrification in Fiji. Section 7.3.2 examines the role for government in rural electrification and the fiscal implications of government electrification policies and objectives. Section 7.3.3 sets out a number of policy recommendations that, if implemented, could improve the sustainability of rural electrification programs. The majority relate to maintenance problems identified by this research. Also discussed is the need for installed systems to meet the demands of households.

7.2 Policy Implications for the Electricity Grid

7.2.1 Revisiting Research Findings and Government Objectives

The portfolio modelling presented in chapter three provided support for renewable technology investments forecast by the FEA. This investment is associated with the FEA's target of generating 90 per cent of power from renewable technologies by 2015, and includes new FEA hydro-power plants and the establishment of biomass, bagasse and geothermal-based power generation capacity by IPPs. In the model, expected average generation costs and financial risk in 2025 fall as a result of these forecast investments, relative to a scenario where there is no further investment in renewable technologies.

Further investment in low-cost, low-risk renewable technologies, beyond that forecast by the FEA, was also supported by the modelling. In the “best case” scenario for 2025, additional investment in energy efficiency measures, and geothermal, biomass and bagasse technologies, significantly reduces both expected average generation costs and financial risk. The model found that investment in energy efficiency measures, and geothermal, biomass and bagasse technologies, was more beneficial than investment in hydro-power, which requires significant back-up oil-based generation capacity.

The modelling results raised questions about FEA investment in hydro-power generation capacity. Why has the FEA chosen to prioritise investment in hydro-power over other technologies that the modelling presented here suggests lower costs more significantly and have a similar impact on financial risk? The discussion in chapter four speculated that this was the result of several factors, including rate of return regulation, which guarantees returns on investments with high upfront costs; past FEA experience with renewable technologies, including its successful investment in the Monasavu hydro-power scheme and its failed investment in the Butoni wind farm; and the perceived role of other public enterprises in the timber and sugar industries. Energy efficiency measures were also found to run contrary to the FEA’s commercial objectives of selling power.

The likelihood of the FEA achieving its target of 90 per cent power generation from renewable technologies by 2025 was also questioned in chapters three and four. A number of barriers to investment in low-cost, low-risk renewable technologies were identified. The most important is access to financing. Access to financing has been made more difficult by the uncertain political climate in Fiji, with political instability resulting in a number of policy reversals in the power sector, including the failed “unbundling” of the FEA and government reversal of tariff determination by an (ostensibly) independent body. This political and regulatory uncertainty has contributed to limited IPP investment to date.

A number of other barriers to renewable technology investment were also identified in previous chapters. In the sugar industry for instance, forecast investment in bagasse-based power generation is tied to the fortunes of the Fiji Sugar Corporation (FSC), given its monopoly on purchases of sugar cane. The future of the FSC is highly uncertain, despite recent government intervention. These issues are explored in the sections that follow, together with a number of other barriers to renewable technology investment not previously discussed.

7.2.2 Financing and Political Uncertainty

Recent reform of the tariff determination process and corresponding increases in retail and feed-in tariff rates provide the FEA and IPPs with commercial incentives to pursue renewable technology investments. This was outlined in chapter four. Investment however has been limited by a lack of access to financing and political uncertainty, especially among IPPs. The FEA has not faced the same constraints, given government support for its renewable technology investments. It has nonetheless been cautious about accumulating debt, and is likely to lose government support in the form of debt guarantees once partially privatised. This means that FEA access to finance could become a more significant challenge in the near future, despite equity finance injected as a result of privatisation.

This section begins by discussing financing options that are available to the FEA. It later discusses IPP financing of projects. The section concludes with a discussion about donor support for investment in renewable technologies, including international frameworks such as the Clean Development Mechanism (CDM) and possible future carbon market finance.

FEA Financing Options

The FEA relies on external financing for its major projects. This is common for power sector utilities, which generally have higher debt to asset ratios than companies in other sectors of the economy due to the capital intensive nature of power generation, transmission and distribution (Choynowski 2004). Financing issues are also particularly relevant for renewable technologies, due to their high capital cost.

Financing can be broadly categorised as debt financing, where a utility borrows to fund an investment, and equity financing, where investors assume a share of an investment (Modigliani and Miller 1958; Vivid Economics 2009; Wade 2005a; Ward 2010). The cost of equity capital tends to be higher than the cost of debt finance, as it involves higher risk, with returns to investors based on profits from the project (Modigliani and Miller 1958). Investment projects commonly involve a mixture of equity and debt financing, with initial equity finance used to attract lower-cost debt finance (Nevitt and Fabozzi 2000; OECD 2007; Ward 2010).

Past Financing Arrangements

The FEA has relied primarily on debt financing in the past to fund renewable energy projects. Its access to debt financing has been facilitated by the Government of Fiji, which has provided the FEA with debt guarantees so that it can borrow money at lower interest rates. The importance of debt guarantees for the FEA has made the Fiji Government a significant player in decisions relating to large-scale projects, and has reduced the independence of FEA management. This was discussed in chapter four.

The financing arrangements for the two largest electricity sector investment projects in Fiji illustrate how the FEA has financed past renewable technology investments. The Nadarivatu hydro-power scheme has been financed by a combination of FEA domestic bond issues, a private sector loan, and a low-interest loan from the China Development

Bank.[171] Both the private sector loan and the loan from the China Development Bank were facilitated by the provision of a debt guarantee by the Government of Fiji (FEA 2007a; FEA 2007b; FEA 2008a; FEA 2008b; FEA 2009a; FEA 2010). In the case of the Monasavu hydro-power scheme, the Government of Fiji assisted the FEA more directly by providing a FJ$43 million grant and a FJ$5.5 million loan. Other loans to the FEA for construction of the Monasavu hydro-power scheme were also guaranteed by the Government of Fiji (Chaudhari 1995). These arrangements are illustrated in table 7.2.2a.

Table 7.2.2a Sources of Financing for Major Electricity Infrastructure Projects in Fiji ($FJ million*)

	Monasavu Scheme (commissioned 1983)	Nadarivatu Scheme (due to be commissioned in 2012)
Donor Loans (Concessional)	$137m (38%)	$142m (47%)
International Private Sector Loans	$4m (1%)	
Domestic Loans / Bond Issues	$73m (24%)	$162m (53%)
Government Grants	$43m (14%)	
Government Loans	$6m (2%)	
Other	$37m (20%)	
Total**	$300m (100%)	$304m (100%)

*Dollar figures represent actual loans in Fiji Dollars at the time of the loan. The figures do not adjust for inflation or currency movements. Similarly, loans were denominated in a number of currencies, but are shown here in Fiji Dollars for comparison.

**The total costs of the Monasavu and Nadarivatu schemes cannot be compared using this table. Total costs were very different when inflation is considered, with the Monasavu scheme costing over FJ$1,000 million when costs are calculated in 2009 $FJ.

Source: (Cama 2009; Chaudhari 1995; FEA 2000; FEA 2007a; FEA 2007b; FEA 2008a; FEA 2008b; FEA 2009a; FEA 2010; Government of Fiji 2010a; Rika 2009; World Bank 1980; World Bank 2007)

The FEA has also borrowed from the private sector to fund renewable technology investments. Two sources of private sector debt financing have been particularly important: domestic bonds and large-scale loans. The use of bonds has several benefits for the FEA. First, their financing costs are generally lower than other forms of debt financing. Second, the FEA sets the length and fixed interest rate for bonds, providing it with certainty and

[171] The FJ$70 million loan is subject to interest rate of 7.15 per cent per annum for 60 months. Thereafter the rate will be equal to LIBOR rate plus a margin of 3.2 per annum.

lowering its risk (in many cases bonds are for terms of 10 years). Third, bonds are issued in Fiji dollars, meaning that there is no exchange rate risk.[172]

No data is available on who purchases FEA bonds. It is however likely that bonds are bought by government-controlled organisations such as the Fiji National Provident Fund (FNPF). FEA bonds offer very low real returns; meaning that it is unlikely private sector investors would subscribe. The FNPF on the other hand has had few other investment options in recent years, with the Reserve Bank of Fiji between 2007 and 2010 prohibiting most overseas investments by the FNPF (FNPF 2007; FNPF 2010).

Purchase of low-return FEA bonds by government-controlled entities would amount to government subsidisation of FEA borrowing. This assistance would be in addition to government provision of debt guarantees. Purchase of FEA bonds by government entities would also mean that the Fiji Government is financing FEA capital projects in a non-transparent manner. It is not possible to verify whether this is the case, information on the purchase of bonds is not public; however the strong likelihood again emphasises the importance of government to the FEA in financing renewable technology investment.

Large-scale loans from big lenders have also provided the FEA with funding for renewable technology investments, although loans have tended to be short-term in nature. For example, in 2007-08 the ANZ Bank in Fiji provided the FEA with a US$30 million loan over a three year period to finance construction of the Nadarivatu hydro-power scheme (FEA 2007a; FEA 2008a; FEA 2010).

[172] The latest bond issues by the FEA were for the Nadarivatu scheme. Depending on their maturity date, these bond issues guaranteed investors annual returns of between 3.01 and 8.95 per cent (for the 2007 bond issue), and 3.43 and 7.19 per cent (for the 2008 bond issue), over a one to 15 year period in Fiji dollars (FEA 2007a; FEA 2008a; FEA 2009a). The cost to the FEA of these loans is minimal considering the inflation rate in 2010 was 5.5 per cent (Fiji Islands Bureau of Statistics 2011a). The domestic bond issue raised US$50 million towards the financing of the Nadarivatu scheme, or 53.33 per cent of the scheme's total cost. For the Monasavu scheme, domestic loans and bonds combined raised FJ$73 million (1982 Fiji dollars), or 30.48 per cent of the total cost of the scheme. Bonds formed only a small portion of this, with domestic loans being more important (including loans from the Fiji National Provident Fund and the Suva City Council) (Chaudhari 1995). Bonds were also issued by the FEA in 2001 (FJ$44 million), 2003 (FJ$15.6 million), and 2005 (FJ$30 million) to fund the purchase of diesel generators, and to pay for diesel fuel in times of high oil prices and drought (Rika 2009).

Private sector financing of FEA projects has its limitations. Domestic bonds are the financing method preferred by the FEA, but there is a limited amount of money that can be raised from domestic bonds. As a result, bonds have only ever partially financed large-scale renewable technology projects pursued by the FEA. Large-scale loans from the private sector are another option available to the FEA, although again there are limits to private sector capital that is available in Fiji. Large-scale loans from the private sector in the case of the Nadarivatu scheme also had the disadvantage of being for short time periods; exposing the FEA to risk in the case that the loans were not rolled over by the creditor, or if terms were very different from the original. Private sector loans from overseas have not been used to a great extent by the FEA, and are likely to involve higher interest rate payments (given the perceived political risk in Fiji).

Equity financing has been used to a more limited extent by the FEA. Equity finance facilitated FEA investment in two small-scale hydro-power projects, the FJ$5.7 million Vaturu (otherwise known as Nagado) and FJ$15.45 million Wainikasou schemes (Pacific Hydro 2010). This was done through a joint venture, Sustainable Energy Limited, which was formed in 2003 by the FEA and Pacific Hydro Limited (an Australian company). Sustainable Energy Limited also developed the early stages of the Butoni windfarm and the Nadarivatu hydro-power scheme, but in both cases Pacific Hydro Limited withdrew citing low returns (FEA 2007a; FEA 2008a; FEA 2009a). The prediction of low returns was correct in the case of the Butoni wind farm, and it remains to be seen whether the Nadarivatu project can generate a commercial return (although recent tariff increases will assist in this respect). Pacific Hydro Limited appears to have recently withdrawn from Fiji's electricity sector, with the FEA purchasing its 50 per cent stake in Sustainable Energy Limited in 2010 (FEA 2010).

The way the FEA finances future renewable technology investments is set to change with its partial privatisation. The interim Minister for Public Enterprises flagged that 49 per cent of the FEA will be sold through the South Pacific Stock Exchange in late 2011. The government has stated that an important reason for the partial privatisation is to facilitate the injection of private sector capital into the FEA (Baselala 2010a). Chapter four argued that the fiscal benefits of the sale were more probably the main motivation for government.

The partial privatisation will enable the FEA to pursue renewable technology investment with the injection of private sector equity finance into the FEA. It seems unlikely however that this inflow of capital alone will be sufficient to fund the FEA's renewable energy program. The FEA's 2010 annual report estimates that investment of FJ$1.5 billion will be required by 2015 to enable the FEA to achieve its 90 per cent renewable energy target. This includes investment in generation capacity, and transmission and distribution infrastructure. The FEA forecasts that approximately FJ$300 million of this will come from IPPs. The remaining FJ$1.2 billion will come from the FEA (FEA 2010).

It is difficult to speculate about what portion of this financing requirement will be financed by the injection of equity finance associated with the FEA's partial privatisation. The size of this capital injection, along with the share price, is uncertain. A crude estimate indicates that the partial privatisation could generate approximately FJ$200 million, based on the FJ$415 million valuation of FEA net assets in 2010 (FEA 2010). The actual capital injection will almost certainly differ from this due to many factors, including market expectations for the future of the FEA. Regardless, the crude estimate suggests that the partial privatisation alone will not enable the FEA to finance the aggressive investments in renewable technologies advocated in the portfolio modelling in chapter three. Other sources of financing will also be required.

Debt financing remains an option for the FEA, which is in a position to assume more debt. The gearing ratio of the FEA, as measured by net debt divided by total capital, was 41.6 per cent on 31 December 2010. This is not a high gearing ratio compared to that of electricity utilities in other parts of the world. For example, the gearing ratio of power utilities in the

OECD averaged approximately 52 per cent between 1991 and 2002 (OECD 2007). In a study of 90 publicly listed power utilities in developing countries, Correia da Silva, et al. (2004) found an average gearing ratio of 44 per cent. The FEA is nonetheless cautious about assuming more debt. In its 2010 Annual Report, the FEA stated it intended to maintain a gearing ratio below 45 per cent, which it considers the "international benchmark for power utilities".[173] This low gearing ratio will limit the FEA's ability to directly finance renewable technology investments through debt financing.

The use of joint ventures is another option available to the FEA. Project-specific joint ventures could attract equity capital for renewable technology investments. This could in turn be used to attract debt financing for the same projects. This sort of funding arrangement is typical of energy sector projects, with debt to equity ratios of 70/30 being very common (Ward 2010). Attracting equity financing may nonetheless be a challenge, considering political uncertainty in Fiji. The FEA's past experience with joint ventures, summarised in the next sub-section, emphasises this point.

The privatisation of the FEA may make accessing debt financing more difficult (and expensive) if it means that the FEA no longer receives a government debt guarantee. This is a likely outcome. Continuation of the debt guarantee would mean that government was directly supporting private sector investors, which would be unpopular among voters, other public enterprises, and potentially IPPs. It is therefore possible that the FEA could face higher borrowing costs and/or difficulty in attracting capital for renewable energy projects as a result of the partial privatisation; despite government intentions to the contrary.

The future regulatory framework and whether or not it is perceived by foreign investors to provide stability and certainty will be important in this respect. The risky investment environment in Fiji, caused primarily by political instability, has been flagged in the past as a barrier to financing of renewable technology projects (EcoSecurities Ltd 2005; McGregor 2009). Political risk is also a barrier to broader private sector investment in Fiji, and has worsened in recent years (Bulatale and Duncan forthcoming; Mahadevan 2009a; Prasad

[173] In 2006, a maximum leverage ratio was included in the performance objectives of the FEA. No such target has been included in subsequent performance objectives (FEA 2006; FEA 2007a; FEA 2008a; FEA 2009a; FEA 2010).

2010; Prasad and Narayan 2008). The impact of political risk is discussed in more detail with reference to IPP investment below.

The tariff determination process and tariff levels are also an important element in the incentives of potential investors, given their impact on the revenues of power generators. These are also affected by political uncertainty. Key questions for potential investors are whether the Commerce Commission will retain control over tariff determinations, and whether it will continue to set high tariffs with the goal of facilitating renewable technology investment.

Independent Power Producers

Investment in power generation capacity by Independent Power Producers (IPPs) offers another means of financing investment in renewable energy technologies. Attempts to attract private sector financing through IPP investment in renewable technologies have to date largely failed, although this now appears to be changing. Past investment by IPPs in Fiji has been limited largely as a result of low feed-in tariffs offered by the FEA, an issue that was discussed in chapter four (section 4.2.3).[174] The establishment of a minimum feed-in tariff by the Commerce Commission has now resolved this barrier to investment, with the FEA now offering feed-in tariffs that are high enough to attract IPP investment.

Access to finance nevertheless remains a barrier to IPP investment in Fiji, and has been worsened by political uncertainty in Fiji. Periods of political unrest in Fiji have commonly involved destruction of private property, as occurred in the civilian overthrow of the FLP government in 2000. Land-related conflicts have also escalated during periods of civil unrest, as occurred when landowners occupied the Monasavu hydro-power scheme in 2000. Political uncertainty is closely linked to regulatory uncertainty. Chapter four outlined how frequent changes of government had undermined the reform process, in many cases leading to policy reversals. These regulatory risks are significant for IPPs that are considering investment in Fiji's power sector. Political uncertainty has been highlighted as a barrier to access to finance in a number of IPP projects. In the case of the Vaturu and Wainikasou

[174] Non-financial barriers to IPP investment are discussed in section 7.2.3.

hydro-power schemes, access to Clean Development Mechanism funding was considered essential to the viability of the project (EcoSecurities Ltd 2005). Pacific Hydro Limited is also said to have withdrawn from its joint venture with the FEA as a result of political instability (McGregor 2009).[175]

In the case of the Vuda biomass scheme more recently, Pac Energy (the investor) attributed delays in the investment to difficulties accessing finance. Pac Energy stated that such difficulties were the result of several factors. One issue was the negative investment environment caused by the global financial crisis, which increased risk aversion and reduced appetite for equity investments. Another issue was that domestic lending institutions were focused on existing projects, making access to domestic finance difficult. Perhaps most importantly, Pac Energy argued that it encountered difficulties accessing overseas financing as foreign investors looked to larger markets with "better perceived risk/return characteristics" (Pacific Renewable Energy Limited 2011). This statement implies that investment in Fiji was perceived as high-risk by potential investors, given that expected returns from the Vuda project are very attractive (in the order of 23 per cent per annum).[176] The investment is proceeding due to a FJ$23 million debt guarantee from the New Zealand Export Credit Office (a New Zealand Government agency) (Correspondence with NZAid, September 2011; Pacific Renewable Energy Limited 2011).

The experience of Pac Energy in attempting to access financing is consistent with broader investment trends observed by the World Bank. It notes a tendency for Foreign Direct Investment to flow to large developing countries that have better "enabling environments", larger markets, and lower perceived risk (World Bank 2010b). Difficulties in accessing domestic finance are also consistent with experience around the world in recent years, as investors have become risk averse and sought to consolidate existing investments as a result of financial instability (World Bank 2010b).

[175] McGregor (2009: 166) states that Pacific Hydro Limited initially pursued the Vaturu and Wainikasou projects as "a platform for larger CDM projects within Fiji"; but that "the perceived risks associated with recent changes in Fiji's political environment…affected the financial viability of the joint-venture arrangement." These arguments are based on her communications with Pacific Hydro Limited.

[176] Pac Energy was clearly not in a position to explicitly state that Fiji is perceived as a risky investment environment, considering political sensitivities.

Donor Support

Donor funds are another potential source of financing for renewable technology investments. Donors have in the past financed a significant portion of large infrastructure projects in Fiji's electricity sector, as outlined in table 7.2.2a. The Monasavu hydro-power scheme was partly financed by international loans from the World Bank, Asian Development Bank, European Investment Bank, Commonwealth Development Corporation, and the Australian Government aid program. More recently, the Nadarivatu scheme has been partly financed by the China Development Bank.

Since 2006, donor funding of infrastructure projects in Fiji has been seriously affected by sanctions placed on the interim military government, with the cancellation of a number of projects that had been planned prior to the military coup. This follows the partial withdrawal of many "traditional donors" in response to the coup, including Australia, New Zealand, the United States, Japan, and the multilateral banks. Overseas Development Assistance to Fiji declined as a result, as shown in table 7.2.2b.[177]

Table 7.2.2b Overseas Development Assistance to Fiji, 2004-09 (USD million)

2004	2005	2006	2007	2008	2009
65.56	66.14	55.65	50.81	45.25	71.12

Source: World Bank database, http://data.worldbank.org

The decline in aid from "traditional donors" has been partly offset by an increase in aid from China. This has been extensively documented by analysts at the Lowy Institute (Hanson 2008a; Hanson 2008b; Hanson 2009). Aid from Australia, traditionally Fiji's biggest donor, has declined from an annual figure of AU$30.5 million in 2005-06 (before the military coup) to AU$17.6 million in 2009-10 (these figures do not include regional aid programs that target all Pacific island countries). The decline is especially noteworthy given the significant increase in the Australian aid program in the same period (which has resulted in increases in aid to the majority of Pacific island countries) (Australian Government 2005; Australian Government 2011).

[177] Table 7.2.2b also shows a one-off increase in aid to Fiji in 2009, which represents funds transferred to Fiji for construction of the Nadarivatu hydro-power scheme. Figures for subsequent years are not available.

In the electricity sector, infrastructure projects that were cancelled as a result of the coup include an ADB project to install a second transmission line in order to better integrate the eastern, central and western parts of the Viti Levu Interconnected System (VLIS) (Interview with ADB, August 2009).[178] This would considerably improve short-term security of supply in events such as cyclones (ADB 2006; Cheatham 2006; World Bank 2007). Prior to the coup, the World Bank also had plans to finance the installation of additional generators at the Wailoa power plant (at Monasavu) and to install two generation units utilising biomass. Again this project was cancelled as a result of the military takeover (ADB 2006; World Bank 2007; World Bank 2010a).[179]

The Nadarivatu hydro-power scheme is perhaps the best example of a project affected by the military coup. Prior to the coup, the scheme was to have been largely financed by the World Bank and the European Investment Bank (which had already approved a subsidised loan). Sustainable Energy Limited developed the initial project. Donor support was withdrawn as a result of the 2006 coup. Financing from the China Development Bank subsequently became important for the construction of the Nadarivatu hydro-power scheme, replacing loans from the World Bank and the European Investment Bank.

Chinese involvement in the Nadarivatu hydro-power scheme has raised some criticism. The China Development Bank's support for the project was subject to the condition that it be constructed by a Chinese firm, Sinohydro Corporation Limited. Sinohydro's use of Chinese labour and equipment has reduced the Nadarivatu project's benefits to the local economy, with the use of imported workers from China and at least 50 per cent of the construction materials procured in China. The Construction Energy and Timber Workers Union (CETWU) in Fiji has also protested about occupational health and safety violations (Cama 2009; Dornan 2010; Niumataiwalu 2009; The Fiji Times 2009).[180] Nonetheless, Chinese financing has been crucial to the construction of the Nadarivatu hydro-power scheme, given the withdrawal of support by traditional donors.

[178] Key demand centres are in the east (Suva) and west (Lautoka and Nadi), whereas considerable power supplies come from the Monasavu hydro-power scheme in central Viti Levu.
[179] The FEA is now pursuing this option independently.
[180] Sinohydro's international labour record is poor, with the company having been reprimanded in the past by China's State Assets and Supervision Administration Commission (Brewer 2008).

Access to donor financing looks more promising for Fiji in the long term. Recently, the Australian Government announced it would be reversing this decline, doubling aid to Fiji by 2013-14 (AusAID 2011). Political concern regarding Fiji's relationship with China is likely to have played a role in the decision to increase donor assistance to Fiji (Herr and Bergin 2011). Assistance from "traditional donors" is also likely to increase dramatically once elections are held in Fiji; something the military regime has said will occur in 2014.[181]

Climate Change Financing

Market-based Climate Finance

Multilateral efforts to combat climate change offer another potential source of funding for renewable energy projects in Fiji. The largest market-based source of climate change financing for renewable energy projects in developing countries is the Clean Development Mechanism (CDM). The CDM was established in 1997 by the Kyoto Protocol to promote greenhouse gas emission reductions in developing countries. It enables Annex 1 countries (which are generally developed countries or countries in transition) to meet their obligations under the Kyoto protocol by purchasing certified emission reductions (CERs) from projects in non-Annex 1 countries (which are primarily developing countries). Purchasers of CERs may be governments, banks or companies. The CDM was also established with the objective of promoting sustainable development in non-Annex 1 countries, including through the transfer of technology.

The CDM has become an important mechanism for encouraging investment in low-carbon technologies.[182] It generated US$23 billion in CERs value between 2002 and 2008, which

[181] The growing demand for power in Fiji and a lack of spare capacity at existing hydro-power plants means that there is ample scope for donor financing of renewable technology projects. The fact that such projects lower greenhouse gas emissions will also raise their appeal among "traditional donors", and may enable Fiji to attract climate change financing (outlined below). Regulatory reforms implemented in Fiji over the past decade (discussed in chapter four) should also facilitate donor financing.

[182] In the early stages of CDM, the majority of CERs were generated from retrofitting of existing industrial processes, which offered low-cost emission reductions (Ellis, et al. 2007). Since 2006, investments in renewable energy and energy efficiency technologies have become more important with the exhaustion of such "low hanging fruit" (Dawson and Spannagle 2009; World Bank 2010b:40).

should lead to approximately US$106 billion in low-carbon investment (World Bank 2010b).[183] This compares to sustainable energy investment in developing countries of US$80-90 billion over the same period (World Bank 2010b).

The future of the CDM is however uncertain. The first commitment period of the Kyoto Protocol will expire in 2012. A second commitment period was agreed to in the Durban UNFCCC talks in late 2011, but excludes major emitters, such as the United States, Japan, China, Russia, Canada, and Australia. The value of CERs generated after 2012 are now being underpinned to some extent by a European Union announcement that CERs will continue to be accepted under the EU Emissions Trading System post-2012 (Dawson and Spannagle 2009; Klepper 2011; World Bank 2010b), the prospect that Australian emitters may buy CERs from 2015 under Australian legislation entering into force in 2012, and that other countries might make CERs eligible in their domestic schemes. However, the EU – the main buyer to date – is likely to accept CERs from new projects only from least developed countries. The European Commission has also proposed a phase-out of the CDM (Höhne 2011; Klepper 2011). Other potential sources of demand for CERs, such as voluntary carbon markets, are likely to remain limited (World Bank 2010b).

For Fiji, the existing structure of the CDM also limits its potential use for financing of renewable technology investments. Most CDM projects to date have been concentrated in a small number of (mainly large) countries, especially China, India and Brazil. In 2009, China alone enjoyed 72 per cent of the CDM market (World Bank 2010b). CDM finance is similar to Foreign Direct Investment in this sense, being risk averse and flowing to countries with a good enabling environment, including sound and stable regulatory structures. There has been very limited investment in the least developed countries or countries considered to have poor governance.

Limited success in attracting CDM finance in Fiji and other Pacific island countries is also due to the small-scale of projects. Across the Pacific islands, four projects have been approved for CDM finance: two in Fiji, and two in PNG. Projects approved for CDM finance in Fiji are the Vaturu and Wainikasou hydro-power schemes (which are a bundled

[183] Active projects in the CDM pipeline between 2002 and October 2011, if they proceed, are expected to generate 2.7 billion CERs looking forward to 2012 (UNEP Risoe 2011).

project, as discussed below) and the Kinoya sewage treatment plant. The Nadarivatu hydro-power scheme in Fiji is at the validation stage.

The difficulty of financing projects through the CDM has been the subject of a great deal of literature (Bakker, et al. 2011; Michaelowa and Jotzo 2005; Wara and David 2008). One issue has been proving that projects are "additional" to existing investments (see McGregor 2009 for a discussion relevant to the Pacific islands). Another criticism has been the time it takes to evaluate CDM projects and issue CERs, which has increased steadily since 2005 (World Bank 2010b).[184]

The significant issue for small-scale projects in accessing CDM funding has been the transaction costs involved in verifying projects (Loong and Pearson 2004; Michaelowa and Jotzo 2005; Pearson 2004). Figures for Fiji are not available, but Millar (2007) estimated that pre-implementation costs of CDM projects could approximate US$200,000. That figure does not include transaction costs associated with monitoring and certification during the project's lifetime. CDM revenue for small hydro-power projects commonly amounts to 10 per cent of total project cost (Beaurain and Schmidt-Traub 2010).[185]

Perhaps the greatest barrier to using the CDM to finance renewable technology investment in Fiji is that most carbon finance under the CDM is paid on delivery of emission reductions. This is the result of the very structure of the CDM, which seeks to make marginal projects financially viable, not provide upfront financing. Financial institutions can provide a means of addressing this issue by providing loans to investors and receiving CERs upon completion of the project. Examples of such arrangements are few however,

[184] In 2009, it took an average of 572 days for registration of a CDM project, and 607 days for projects to move from registration to first issuance. This would significantly delay construction of a project that relies on CDM funding to be commercially feasible.

[185] The CDM Executive Board has attempted to address this last barrier to small-scale projects through the introduction of "Bundling" and "Programmes of Activities (PoAs)". These mechanisms allow for the bundling of diverse CDM activities in order to achieve economies of scale and make small projects viable. PoAs are particularly flexible, allowing for the addition of new project to a PoA after it has been approved, and since 2009, for projects to be formed across countries. The introduction of bundling and PoAs is significant for Small Island Developing States, although organising a PoA with projects in several countries remains a challenge (EcoSecurities Ltd 2005). In Fiji, the new rules have allowed the "bundling" of CDM credits for the Vaturu and Wainikasou hydro-power schemes, thereby spreading the largely fixed transaction costs across two projects.

given the high risks involved in renewable energy projects (World Bank 2010b).[186] The CDM is therefore limited in the extent that it can raise the upfront capital cost of renewable technology investment in Fiji.

Public Carbon Funds

Carbon funds using public finance from developed countries provide another potential option in addressing the renewable technology financing barrier in Fiji. The Global Environment Facility (GEF) is one of the better known multilateral funds, providing funding for climate change and environmental-related projects. GEF has funded a number of energy sector projects in Fiji related to the electricity grid and off-grid rural electrification. It is currently funding a UNDP-operated project designed to remove barriers to the use of cost-effective grid-based renewable technologies (Global Environment Facility 2011). The main focus of GEF in Fiji to date has however been establishing enabling conditions and “proof of concept” initiatives, not direct financing of commercial grid-based renewable technology projects.

The multilateral Clean Technology Fund operated by the World Bank is another example of a carbon fund. It has recently been established to promote and transfer low carbon technologies to developing countries, with funding up to May 2011 totalling US$1.5 billion (Climate Investment Funds 2011). Pilot programs under the fund are being implemented in larger developing countries, although none targets SIDS. This could change when more programs are established. One potential barrier to the use of the Clean Technology Fund to finance renewable technology investment in Fiji is its emphasis on “significant” greenhouse gas emissions savings (Climate Investment Funds 2011). The small-scale of power sector emissions reductions in Fiji relative to those in larger countries may therefore place projects based in Fiji at a disadvantage, although this remains to be seen.

Future carbon funds established as part of international climate change talks may better address the financing barrier to renewable technology investment. The scale of such carbon funds will increase significantly in the coming decade. Developed countries have

[186] The fact the CDM does not address the issue of upfront financing is one reason that most CDM finance has flowed to countries where finance is already available and investment in renewable technologies is occurring.

committed to providing US$100 billion each year to developing countries for mitigation and adaption by 2020, with the Cancun Agreements establishing a global “Green Climate Fund” to transfer these resources (Jotzo, et al. 2011; UK 2010; UNFCCC 2010). Details on how these funds will be administered are still being negotiated. Experience with the CDM may provide lessons on how to balance the focus of such carbon funds on large-scale greenhouse gas emission reductions with ensuring they remain accessible to small-scale projects. It is nevertheless unlikely that carbon funds will be a panacea to the financing barriers in Fiji already discussed.

Financing: Policy Implications

Access to financing remains the most significant barrier to investment in renewable technologies in Fiji. The FEA is limited in the investment it can undertake without additional government involvement (which is already significant). Donor and private sector financing is therefore likely to be required for Fiji to meet its ambitious renewable energy targets. What policy options are available to the Government of Fiji that could facilitate financing of renewable technology investments by these groups?

Investment by the private sector has been hampered by political instability, which has limited IPP access to finance. Unfortunately, there are no “quick-fix” measures available to the government in addressing this issue. In the long run however, the government can reduce the perceived risk of investment in Fiji through measures aimed at addressing political instability, and ensuring effective and stable regulation in the power sector. Some steps towards the latter objective have already been undertaken. The establishment of an independent regulator that determines electricity tariffs, and its imposition of minimum feed-in tariffs for IPPs, is facilitating new IPP investments in biomass-based power generation. This was discussed in chapter four. Similarly, establishment of a *National Energy Policy*, with defined targets for renewable energy penetration, has demonstrated to potential investors the commitment of government to renewable technologies in Fiji.

The single most important factor influencing perceived risk nevertheless remains political instability. This leads to regulatory instability (as discussed in chapter four), potentially threatens property rights (where land is involved), and can generate law and order problems. Addressing the issue of political instability, although difficult, is therefore essential in facilitating investment in Fiji's power sector. The end of military rule and the establishment of democratic processes will be important in the transition to a politically stable, representative, and effective government. Reconciliation between supporters and opponents of the coup, and between pro-indigenous and Indo-Fijian parties will also be essential in the long term, as will the establishment of a representative democracy, where control of government is not determined by ethnicity. A reduction in the size of the military (or its abolition) would contribute to future political stability by removing the threat of military intervention in politics.

The establishment of a representative democracy would be likely to significantly increase donor-funded concessional finance to Fiji. Investment in renewable technologies is an attractive option for donors, and regulatory reforms in Fiji's power sector have created a sound environment for such investments. Future carbon funds may also prove a source of financing, although it is probable that they will focus on projects with larger carbon emission reductions than those on offer in the Fiji power grid (which is already in large part "green").

7.2.3 Other Barriers to Investment in Renewable Technologies

Non-Financial Barriers to Renewable Technology Investment

There are a number of non-financial barriers to investment in renewable technologies in Fiji. Many of these were raised in previous chapters. Chapter four for example, outlined how the FEA prioritises investment in hydro-power over other low-cost, low-risk technologies. This has been due in part to rate of return regulation, and may change over time with a move towards price cap regulation and as more experience is gained with low-cost, low-risk technologies (including with the appointment of experienced managers). Chapter four also discussed how there is no commercial incentive for the FEA or IPPs to encourage demand side management , given that both profit from the sale of electricity.

A set of barriers to IPP investment in renewable technologies not raised in previous chapters is access to renewable energy resources. Lack of access to renewable energy resources is probably the second biggest set of barriers to IPP investment in Fiji after financing. There are a number of such barriers. One is the process the FEA uses to issue licenses to IPPs. The FEA issues licenses with no timeframe, allowing one IPP to effectively prevent investment by other IPPs in that area at no cost (through its rights over the renewable energy resources) (Interview with Delta Energy, June 2011). As a result, FEA annual reports cite a large number of Power Purchase Agreements (PPAs) being signed with IPPs in the last five years, but record little actual expansion of IPP generation capacity (FEA 2006; FEA 2007a; FEA 2008a; FEA 2009a; FEA 2010).[187] This problem is now being addressed, with the latest PPA to be signed reportedly containing a clause that requires the IPP to commence generation within two years (Bolatiki 2011).

Another even more important issue relates to access to resources for power generation from biomass and bagasse (Interview with Delta Energy, June 2011). Access to these resources among new IPPs is limited. All raw sugar cane must be sold to the Fiji Sugar Corporation (FSC) under the *Sugar Industry Act (1984)*. This effectively gives the FSC a monopoly over the generation of power from bagasse: new IPPs can only generate power from bagasse if contracted to do so by the FSC.

IPPs looking to generate electricity using other sources of biomass also face barriers. Large areas of indigenous land are not used for commercial purposes, and agricultural land in use is dominated by sugar cane production; thereby reducing the availability of land for biomass production (Interview with Delta Energy, June 2011). Biomass from the timber industry is an alternative source of fuel for power production, but access among new IPPs is limited due to the dominance of Tropik Wood (and its parent company, Fiji Pine Limited) over leases of forests on indigenous land. This effectively creates another monopoly situation.

[187] This seems to be the result of past performance targets established by government for the FEA, which included signature of Power Purchase Agreements.

FSC and Tropik Wood are in a position to invest in renewable-based power generation, however new investment by these organisations seems to have stalled, as outlined in chapters three and four. In the case of FSC, this is due to significant financial problems and poor management (described in chapter four). In the case of Tropik Wood, problems with the generator at the Drasa mill have resulted in the cancellation of investment plans (FEA 2007a; FEA 2008a; FEA 2009a; FEA 2010).

Investments by IPPs that are new to Fiji have addressed the issue of access to renewable energy resources by dealing directly with landowners. In the case of the Vuda biomass plant currently under construction, the IPP is providing landowners with equity in a separate company that will sell fuel wood to the biomass plant. The need to establish such arrangements is itself considered a risk by investors. There remains the potential for landowners to later protest against such agreements, as is common in Melanesian countries. The FEA has encountered similar difficulties with the Monasavu hydro-power scheme, where landowners in the past have both physically occupied the Wailoa power station and asked for compensation in the courts. Given continuing conflicts and tensions surrounding land tenancy in Fiji, the need for IPPs to negotiate ongoing long term access to large areas of fuel wood is a very real and significant business risk, and a barrier to IPP investment.

Policy Options

There are several ways the government could address these issues.

The government has a number of options available to promote energy efficiency. One, discussed in some detail in chapter three, is the establishment of energy labelling and minimum energy performance standards (MEPS). This would promote demand side management among consumers of electricity, and according to the model would have significant economic benefits. Another reform the government should consider is revision of building codes so that they are more demanding in terms of energy consumption. The exact impact of such measures is not known, but it would likely be significant in the long-term. Reform in other sectors could also reduce energy consumption. The water supply was flagged as an area where there is scope for greater energy efficiency, although for this to occur wide-ranging reform which gives the Water Authority of Fiji the financial resources it requires to operate effectively would be necessary. A fourth area where there is scope for government action is in regulation of the FEA and IPPs. Through appropriate regulation or legislation, the FEA could be required to consider energy efficiency measures alongside investments in new generation capacity in its submissions to the Commerce Commission. Such arrangements could provide FEA and IPP management with an incentive to promote demand side management.

The government also has various options available to promote generation from biomass and bagasse. Government reform of the sugar sector, which is warranted for broader economic and social reasons, could potentially facilitate power generation from bagasse. Reforms are now underway, although it remains to be seen whether they will succeed. Past reforms have met with limited success. For example, a loan from Exim Bank in India was to have financed the upgrade of FSC sugar mills, and to have established additional cogeneration plants. The loan was not a success, and the government has taken a more interventionist role in sugar sector reform as a result (Fiji Sugar Corporation 2009; Government of Fiji 2010a; Mahadevan 2009b; Prasad and Narayan 2008). Co-generation and provision of electricity to the grid will be essential if the FSC is to remain competitive in the global economy (Interviews with FSC, 2009).

The review of access rights to feed stocks in the sugar and timber industries is warranted (subject to caveats below). For renewable technology investment, it is important that the government facilitate access to land by investors, while ensuring a fair return to landowners. Also important is an end to any monopoly over biomass resources enjoyed by Tropik Wood/Fiji Pine Limited and FSC. Reform of land tenure is already being implemented by the interim government. Future IPP access to biomass resources is likely to improve as a result of these reforms, which include the establishment of a land bank, provision of 99 year leases, and an end to the Native Land Trust Board's monopoly over decisions relating to customary land. The impact of such reforms on IPP access to biomass resources nonetheless should also be considered in the design of land reform.

Importantly, an examination of the broader economic, social and environmental impacts of using land to produce biomass fuel is also required. The trade-off between using agricultural land for food and fuel has been highlighted in recent years, with growing correlations between the prices of oil and various agricultural crops. Power generation from biomass in Fiji is likely to have significant and broad-ranging impacts on patterns of agricultural production. The impacts of these changes on incomes and food security in both rural and urban areas need to be considered.

There are also other uncertainties regarding renewable energy resources. A lack of data on renewable energy resources is a barrier to IPP investment, making projects more risky and access to financing more difficult. The commercial failure of the Butoni wind farm is a good example. An important reason for the failed investment was a lack of data on wind speeds at the site. This is now being addressed by the Department of Energy, which is collecting data on wind speeds around the country (Interview with Department of Energy staff, July 2009).

Similar information issues have prevented investment in geothermal-based power generation. Expensive deep earth drilling is required to confirm geothermal energy resources. Such drilling typically constitutes approximately 25 per cent of the total capital cost of a geothermal power station. This is a costly and high-risk investment; financing of which is difficult (Coutts 2011; Daniel 2010; Nittetsu Mining Consultants Co. Ltd. 2009). A Fiji-based IPP called Geothermal Electric Limited has sought for two years without success to raise capital for drilling in Savusavu (Coutts 2011; Interview with Tim Daniel, November 2010; Daniel 2010). Potential policy options include offering loan guarantees, or similar financial instruments to enable IPPs to conduct exploration. These could potentially by financed by donors.

7.2.4 Summary

Recent regulatory reform in the electricity sector is facilitating investment in renewable technologies, especially with the establishment of minimum feed-in tariffs. The FEA is also pursuing IPP investment and has previously established joint ventures with private sector power companies. At the same time, a number of regulatory barriers to investment in low-cost, low-risk renewable technologies remain.

Power utilities have no commercial incentive to pursue energy efficiency measures under current regulation, as outlined in chapter four. The government should consider a range of measures in response, including changes to building codes, establishment of energy labelling and minimum energy performance standards (MEPS), reform in sectors that consume power (such as the water sector), and regulations that ensure demand side management is considered in the process of tariff regulation. The Commerce Commission should also move explicitly towards a price cap regulation system, thereby increasing the incentive for the FEA to invest in renewable technologies with lower costs than hydro-based generation.

Other barriers to investment in renewable technologies need to also be addressed. Access to financing is particularly difficult for IPPs. This is the result of perceived risk associated with political instability in Fiji, as well as the small-scale of projects and an uncertain global financial environment. The same challenges have not affected the FEA to the same degree, given provision of government debt guarantees. This is set to change in the future, and is likely to make access to debt financing more difficult for the FEA.

In the long term, the government can reduce perceived risk in Fiji by establishing effective and stable power sector regulation. It has already taken steps in this direction. Reducing political instability is more challenging, but is equally (and arguably more) important. An end to the military regime and establishment of democratic processes is an essential step towards reducing perceived risk in Fiji. For broader political stability, reconciliation between different groups will be required, as will the provision of a voice to groups previously marginalised in politics. A representative democracy where politics is not race-based is needed. The military should also be removed from political affairs, and its size considerably reduced.

Donor support is likely to be required if the government is to meet its renewable technology objectives in the *National Energy Policy*. This again highlights the need for elections in Fiji. Establishment of democratic processes would lead to significant increases in “traditional” multilateral and bilateral aid, enabling renewable technology investments to be financed in Fiji.

Carbon financing may also facilitate future investment in renewable technologies, although the details of future private carbon markets and public carbon funds are still being determined. The usefulness of carbon financing in Fiji will depend on the degree to which such funds deal with the issue of upfront capital costs of renewable technologies; an issue that the existing Clean Development Mechanism (CDM) has not adequately addressed.

A number of non-financial barriers to renewable technology investment are also present in Fiji. A broader examination of the economic, social and environmental impacts of using agricultural land to grow biomass fuel is needed, given experience elsewhere in the world. It is important that this occur prior to investment in biomass facilities. Once it is decided that investment in biomass should proceed, access rights to feed stocks in the sugar and timber industries need to be reviewed, given that access is currently limited for “new” IPPs. The review of access rights should be associated with the interim government’s reform of land tenure arrangements; as these reforms have the potential to improve IPP access to biomass resources and facilitate IPP investment.

In the sugar industry, the financial and managerial problems of the FSC remain a significant barrier to power generation from bagasse. Government reform of the sugar sector, including reform of the FSC and of land tenure arrangements, may potentially address this issue. For power generation from geothermal energy, high upfront exploration costs remain a significant barrier to investment. The government could consider using (donor-financed) loan guarantees to address this issue.

7.3 Policy Implications for Rural Electrification

7.3.1 Revisiting Research Findings

Energy supply and rural electrification of off-grid areas in Fiji was explored in chapters five and six. A survey was conducted in rural areas in Vanua Levu as part of this research to examine the impact of rural electrification and high oil prices on households. The provision of electricity was found to benefit households in a number of ways. The advantage mentioned most frequently by households was that power enabled children to do homework at night. Households which used electricity were also found to spend less on energy, and to be less vulnerable to increases in fuel prices, especially where a battery ensured that lighting services were available whenever required.

Significant problems were discovered with systems installed by the Department of Energy under the *Rural Electrification Policy (1993)* and the *Renewable Energy Service Company (RESCO) Program*. Power outages were common among both solar home systems (SHS) and village diesel systems. For diesel generators, power outages were the result of both technical issues and failure to collect money for maintenance and fuel purchases. These activities are the responsibility of villages under the *Rural Electrification Policy (1993)*. Problems in collecting money were due to electricity supply being a non-excludable good, with households receiving electricity regardless of whether they contributed to the operation and maintenance of the generator. Weather events and fuel distribution problems caused a small number of power outages.

Technical issues were responsible for the majority of power outages that affected SHS. This was the result of the failure of the *RESCO Program* to provide adequate maintenance to installed systems. The analysis in chapter six found that the *RESCO Program* had failed in this respect due to information asymmetries between the Department of Energy and the private sector RESCO responsible for providing maintenance. Information asymmetries led to principal-agent and motivational problems, resulting in RESCO workers not providing satisfactory maintenance to SHS. Inadequate resourcing of the Department of Energy contributed to its failure to properly monitor the RESCO. Bureaucratic procedures the

Department of Energy uses to purchase spare parts also contributed to lengthy power outages among installed SHS.

7.3.2 Government Rural Electrification Objectives and Policy

This section looks at the objectives of government rural electrification assistance, exploring their fiscal implications and whether they are achievable. It also examines why there is a role for government in facilitating rural electrification in Fiji. The section that follows discusses policy options specific to the *Rural Electrification Policy* and *RESCO Program*.

The Government has established a target of 100 per cent electrification in Fiji by the year 2016 as part of the 2006 *National Energy Policy*. The analysis in chapters five and six supports such a target, given the economic, financial, and social benefits of electricity supply. These benefits include both tangible, immediate financial and social benefits, described previously; and intangible, potential future benefits such as economic development resulting from improved educational outcomes. The provision of electricity to un-electrified households is therefore worthwhile both from a broader economic perspective and from the perspectives of rural households.

A related question is whether and how government should be involved in the provision of power to un-electrified households. Government involvement can be justified on the grounds that un-electrified households would generally not be able to access electricity without government assistance. This is the result of several factors. Most important is the financing issue. Rural electrification involves significant upfront costs, which un-electrified rural households would typically not be able to afford (this should be distinguished from operating costs, which the survey data in chapter five showed were affordable for most households). Un-electrified households are generally not able to access loans through the financial sector, due to market failures (discussed in chapters five and six).[188]

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[188] These market failures relate to information asymmetries, where financial institutions know little about the incomes of rural households. Such households commonly do not have collateral, with indigenous-owned land not able to be sold under Fijian law. These issues were discussed in chapters five and six.

Government involvement in rural electrification that extends beyond the provision of loans can also be justified. For village diesel generators, electricity is effectively non-excludable, meaning that households are less likely to contribute to the purchase of a generator in the absence of government involvement (as outlined in chapter five). Another issue is the lack of information in rural communities about electricity generation technologies, especially new technologies such as solar photovoltaic technology. This was clearly visible in the fieldwork presented in chapter five. Information and knowledge gaps are difficult to address, given the remoteness of many rural communities and a lack of access to information and communication technologies. Government oversight and/or direct government provision of power generation technologies is therefore justified.

What of the fiscal implications of the 100 per cent electrification target established by the government for 2016? Households with no access to electricity comprised 11 per cent of the population in the 2007 census, which provides the latest set of comprehensive figures. This means that approximately 19,389 households were without any supply of electricity in 2007.[189] Can this number of households realistically be provided with an electricity supply? What resources need to be committed for the government to achieve this target?

The exact fiscal implications of the government's rural electrification target depend on rural electrification policy. Two hypothetical scenarios are considered here: one in which all rural electrification is conducted with SHS under the *RESCO Program*; and one where half is conducted with SHS, and the other half with the installation of village diesel generators. The first scenario is based on the preference for SHS shown by households in recent years, which were discussed in chapters five and six. The second scenario assumes that demand for diesel generators returns to historical levels. This could occur given waiting lists and problems associated with the *RESCO Program*, and the fact that a majority of un-electrified households are indigenous Fijian (and therefore will in most cases reside in a village where power can be supplied through a mini-grid system).

[189] This figure is calculated from 2007 census data, on the basis of a population 837,271 and average household size of 4.75. The calculation does not account for variation in household size between rural and urban areas, which 2007 census data indicates is minimal.

Estimated total and annual costs to the government of achieving its electrification target by 2016 are set out in table 7.3.2a. The average capital costs of SHS (FJ$4,065) and diesel generators (FJ$2,737) were provided by the Department of Energy, as outlined in chapter five. These are multiplied by the number of un-electrified households in Fiji to estimate the total upfront cost of electrification in row two. An annual figure looking forward to 2016 is provided in row three. Estimates assume that costs remain constant in the future (considering the short timeframe being discussed, this is not unreasonable).

Table 7.3.2a Cost of 100 per cent electrification by 2016

		Scenario 1: Use of only SHS	Scenario 2: Use of SHS and diesel generators*
1	Average upfront cost per household (2009 FJD)	2,737	3,401**
2	Total cost (2007-2016) ($FJ million)	78,800,000	65,900,000
3	Annual cost ($FJ million)	8,800,000	7,300,000
4	Government portion of annual cost (95 per cent for diesel systems, 100 per cent for SHS) ($FJ million)	8,900,000	7,200,,000
5	Total annual cost to government of rural electrification*** ($FJ million)	18,100,000	15,600,000

*This scenario involves electrifying half of all un-electrified households with SHS, and the other half with diesel generators
**This is the average of installation costs for SHS and diesel generators.
***Total rural electrification costs also include the cost of the 54 per cent of rural electrification projects that do not target un-electrified households.

The government pays 95 per cent of the upfront cost of rural electrification projects under the *Rural Electrification Policy (1993)*. This applies to village diesel systems. SHS are installed under the *RESCO Program*, under which households do not contribute to the repayment of the capital cost of SHS (as discussed in chapters five and six). As a result, the fiscal impact of rural electrification where installation of diesel generators is involved is slightly lower than its actual cost, as shown in row four.

Both scenarios assume that un-electrified households are provided their first electricity connection by an off-grid system. This is a reasonable assumption. Although grid-based electricity connections account for over half of all installations under government rural electrification programs, almost all households when first connected to the grid already have an off-grid power supply.[190] This has implications for calculating the fiscal impact of government rural electrification objectives.

In the bottom row, it is assumed that only 46 per cent of government rural electrification projects actually target un-electrified households, with 54 per cent involving extension of the grid to households that have an off-grid electrification system installed. This is consistent with data on rural electrification projects presented in chapter five. The cost of achieving the government target of 100 per cent electrification by 2016 is more than double as a result.[191]

How do these estimates compare to the government budget for rural electrification? Chapter six showed that only in 2009, when the government rural electrification budget was FJ$17 million, did the rural electrification budget come near to the amount required for achieving the government's target of 100 per cent electrification by 2016. The figures for that year are also misleading, given that 92 per cent of projects in that year involved extension of the electricity grid (meaning they did not target un-electrified households). That means that in no year has there been installation of off-grid systems that is sufficient to meet the 2016 target.

The annual funding required to meet the government's objectives is nevertheless modest. The figure of FJ$18 million required in scenario one is an upper estimate. It assumes that: demand for diesel systems collapses, with all new off-grid electrification demand met by high-cost SHS; no donor funding is provided; there is no decline in the cost of SHS; and there is no change to rural electrification policies, which presently do not prioritise un-electrified households and require no contribution from households to the capital cost of SHS under the *RESCO Program*. These are a strong set of assumptions.[192]

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[190] This was outlined in chapter five as being due to the proximity of such households to commercial centres and markets, which greatly increases income-earning opportunities. Connecting households to the grid that already have an off-grid system installed is consistent with rural electrification policy objectives, which aim to eventually provide all households with a 24-hour electricity supply.

[191] Donor funding for rural electrification is not considered. Chapter six demonstrated that such funding is highly unpredictable and in many years is non-existent.

[192] There is at the time of writing anecdotal evidence of significant decreases in the cost of SHS, due to increased supply from China.

The upper annual estimate of FJ$18 million is relatively minor when compared to the $1745.7 million the government received in revenue in 2011 (or the FJ$1,961.7 million it spent) (Government of Fiji 2010a). The opportunity cost of such expenditure would be equivalent to approximately 1 per cent of the budget; a figure that is not insignificant, but is clearly within the means of the government if it considered rural electrification a priority. Donor funding for rural electrification, although welcome, is therefore not a pre-requisite to achieving the government's 100 per cent electrification target.

Concerns about ongoing costs for the *RESCO Program* were raised in chapter five. It was estimated that the monthly cost of providing maintenance to a SHS was FJ$18.72, or FJ$4.72 higher than the amount charged to customers. This amounts to a FJ$56.64 per year subsidy for each household. If it is assumed that all 19,389 un-electrified households in Fiji are provided with a SHS in order meet the government's electrification objectives (as in scenario one), and the existing 2,000 households with SHS installed under the RESCO scheme are also included, the Department of Energy would be required to provide an annual maintenance subsidy of FJ$1,211,472.

This could threaten the sustainability of installed systems if the Department of Energy's budget is not increased by the requisite amount. The failure to do this however would be a political decision, or an institutional failure, not a financial necessity. Once again, the amount (which would total slightly over FJ$19 million) is within the means of the government if considered a priority. The alternative is to review the fee structure of the *RESCO Program*. A modest fee increase is supported in this dissertation, given that almost all households surveyed for this research agreed that they could pay more for SHS installed under the *RESCO Program*.

The principal challenge in "scaling up" off-grid electrification is therefore not financial, but institutional. A barrier to increasing off-grid electrification projects is the limited resources that are available in the Department of Energy, the Public Works Department (which commonly installs diesel-based systems), and the private sector, for installing large numbers of off-grid electrification systems. Some of these resource limitations/capacity constraints were discussed in chapter six. The failure of successive governments to provide annual funding for rural electrification of FJ$6 million, promised under the *Rural Electrification Policy* (1993), has meant that there is not the capacity in Fiji to immediately increase the number of off-grid electrification projects. For this to occur, training of new technicians and a modestly increased budget for the implementing agencies would be required.

7.3.3 The Rural Electrification Policy and RESCO Program

The analysis of the *Rural Electrification Policy* (1993) and *RESCO Program* in chapters five and six pointed to a number of policy implications. Some of these are also relevant to the government's goal of achieving 100 per cent electrification by 2016. The most important theme in the analysis of off-grid rural electrification projects was sustainability, in the sense of ongoing operation of the schemes. Electricity provided by both diesel and solar-based off-grid systems is subject to frequent and prolonged power outages, threatening the sustainability of such schemes. These failures are the result of institutional arrangements for operation and maintenance, as summarised in section 7.3.1. Another issue with the schemes surveyed as part of this research is that they did not adequately meet the needs of households. This limits the usefulness of installed rural electrification systems, and also threatens their sustainability. Households are less likely to pay fees, provide proper maintenance, and are more likely to abuse systems that do not meet their needs. Such issues need to be addressed as rural electrification expands in Fiji.

A number of policy recommendations relevant to the *Rural Electrification Policy* and *RESCO Program* are listed below under different themes. Maintenance is the most important, given the extent of power outages affecting off-grid systems and their origin in poor maintenance arrangements. The failure to provide maintenance under the *RESCO Program* needs to be addressed before it is expanded beyond Vanua Levu (as argued in chapter six). Other recommendations relate to installed systems meeting the needs of households, and the appropriate contribution that beneficiaries should make towards installations.

Maintenance under the RESCO Program

Maintenance problems under the *RESCO Program* are significant, and result primarily from information asymmetries. Directly linking RESCO revenue with the performance of SHS could potentially overcome principal-agent problems, by lessening the need for the Department of Energy to monitor RESCO activities. At the same time, some oversight of RESCO activities will be required to ensure the RESCO services all SHS. The introduction of a complaints mechanism by the Department of Energy could assist it to fulfil this role.

The other significant problem with the *RESCO Program* identified by this research is the time taken to supply spare parts. The RESCO currently orders parts from the Department of Energy, which purchases them in order to achieve economies of scale. Delays in the supply of spare parts have resulted in long power outages of SHS. The RESCO should be responsible for directly purchasing SHS components in order to avoid such delays. The RESCO will have an incentive to ensure the timely supply of spare parts if its revenue is dependent on the functionality of SHS (which is also recommended here).

Maintenance of diesel generators

Improving maintenance of diesel generators is more difficult for government, given community ownership and operation of generators. Options should nonetheless be explored. Two recommendations were made by the *Review of the Rural Electrification Policy* (Matakiviti and Pham 2003). Neither has been implemented. One involves the establishment by communities of "sustainability funds" which can be used to pay for maintenance of a diesel generator (this was also provided for in the 1993 *Rural Electrification Policy*). A barrier to implementing this recommendation is that communities are unlikely to deposit money into such a fund. The Department of Energy could explore ways to encourage communities to deposit money into sustainability funds, possibly through education initiatives and co-contributions by government. The other recommendation in the *Review of the Rural Electrification Policy* was removing the 3-year grace period, in which the Department provides all maintenance to an installed generator. The grace period was found to have no policy objective and served only to increase the dependency of communities on the Department of Energy.

The government should also review and improve the education and training offered to communities when a generator is installed. Content of training should include both technical issues (basic maintenance and operating instructions) and recommended ways of establishing systems so that sufficient funding for fuel and maintenance can be collected.

Electrification to meet the needs of households

For electrification to be sustainable, installed systems must meet the needs of households. For the *RESCO Program*, this means replacing the “one-size-fits-all” approach with one that offers different services. Chapter five outlined how the Department of Energy limits the services provided by SHS to lighting in order to keep costs low. This suits some low-income households, but many other households are frustrated as a result, with some survey respondents admitting to having tampered with the SHS battery in order to power appliances. SHS installed under the *RESCO Program* should instead be of different sizes in order to accommodate the demands of all households. The cost of SHS that provide additional services would need to be considered in the monthly fee charged to users.

For diesel systems, the most significant problem expressed by surveyed households is that lighting is only available for several hours a night. This severely limits the financial benefits of electricity provision for households. The problem could potentially be addressed for new systems if household batteries, charged by the generator, were installed for the provision of lighting when the generator is not functioning. This should be considered by the government, given the economic, financial and social benefits that 24-hour lighting availability would entail.

Contribution of rural electrification beneficiaries to installed systems

The fees charged to users under the *RESCO Program* do not meet their stated purpose of covering maintenance costs and a portion of the capital cost of SHS. The government should review the amount paid for SHS under the *RESCO Program*. Issues to be considered in this review include:

- The effect of the low upfront cost in moving demand towards SHS and away from diesel generators. Should the upfront cost charged to households in the *RESCO Program* and *Rural Electrification Policy* be made comparable? The answer depends on the objectives of the Government of Fiji (the current framework which encourages households to choose SHS is not the result of government objectives).
- The impact of the current fee structure on the sustainability of the *RESCO Program*. The current fee structure involves government subsidisation of ongoing SHS maintenance costs. This is not consistent with the rural electrification objectives of the government. If the government makes a budgetary decision to subsidise ongoing (as opposed to capital) SHS costs, this decision should be made explicit with corresponding financial support provided to the Department of Energy.
- The financial impact of any increase in fees on households should be of central importance in any review. The survey conducted for this research suggests that a majority of households could afford to pay more for a SHS. The introduction of different-sized systems could provide the equivalent of a lifeline tariff for poorer households which could continue to pay FJ$14 for small SHS that provide only lighting (there is also potential for cross-subsidisation of smaller SHS by larger SHS if different sizes were introduced).

7.3.4 Summary

The Government of Fiji is not on track to achieve its goal of 100 per cent electrification by the year 2016. Additional resources need to be dedicated to electrification of un-electrified households if the government is to achieve this target. Funding that is required is nevertheless modest when compared to grid-based renewable energy projects or other government expenditure. Barriers to electrification of all households in Fiji are primarily institutional, not financial. Appropriate financial and human resources also need to be provided to the Department of Energy in order for it to implement the government's rural electrification agenda. Capacity constraints are currently a major barrier to the expansion of off-grid rural electrification.

Reform of rural electrification programs is necessary if electrification of households in off-grid areas is to be sustainable. A number of policy recommendations relating to the *Rural Electrification Policy* and *RESCO Program* are outlined in this section. The majority are focused on improving maintenance arrangements. For the *RESCO Program*, a central recommendation is movement of fee collection responsibilities to the private sector RESCO, as this would remove the need for detailed monitoring of RESCO activities by the Department (which is under-resourced for the role). For diesel generators, the establishment of "sustainability funds" by communities is recommended, with co-contributions from government a means of encouraging community use of such funds. Other policy recommendations relate to ensuring that installed systems meet the demands of rural households, and making government subsidisation of operating costs explicit, with corresponding resourcing of the Department of Energy for this role.

7.4 Conclusion

This dissertation has identified several key policy implications. The portfolio analysis in chapter three suggested that investment in renewable technologies could lower future costs and financial risk in the electricity grid. Most beneficial in the model were investments in low-cost, low-risk renewable technologies, such as energy efficiency, geothermal, biomass and bagasse technologies. Regulatory arrangements in the power sector were found in chapter four to facilitate investment in renewable technologies as a result of recent reforms, although rate of return regulation was found to be partially responsible for the FEA's continued prioritisation of hydro-power investment (despite its higher cost relative to other renewable technologies). This is expected to change with apparent moves towards price cap regulation and experience with other technologies.

Several other barriers to investment in renewable technologies also remain. The most important is access to finance. Independent Power Producers (IPPs) have found it difficult to finance investments in Fiji, given political uncertainty and a perception of regulatory risk. The FEA has not suffered the same problem, given the provision of government debt guarantees. This is set to change with the FEA's partial privatisation, as continued provision of debt guarantees would be inconsistent with the FEA's partial privatisation (exposing taxpayers to financial risk while benefiting shareholders). Access to finance may therefore become a challenge for the FEA in the future.

The Fiji Government has limited options available for addressing this barrier to investment. Measures that reduce perceived risk in Fiji are promising in the long-term, and include stable and effective regulation in the power sector, as well as political measures aimed at promoting reconciliation and political stability. The end of military rule is important in the short-term, as is the establishment of a representative democracy in the long-term. Donor financing is likely to be a very important source of funding for grid-based renewable technology investment, and should increase post-2014 (the year the interim military government has set for elections). International carbon financing measures may also be a source of financing for power utilities in Fiji, although their design is yet to be determined. Existing carbon funds have had only a minimal impact on Fiji's power sector.

A number of other barriers to renewable technology investment can also be addressed by policy-makers. Discussed in chapter four were the benefits of moving towards price cap tariff regulation, preventing the decline of the sugar industry, and promoting greater energy efficiency. The government appears to be moving towards price-cap regulation and is supporting reform in the sugar industry, although it remains to be seen whether these actions will be effective. Less is being done in the area of demand side management. The government has considerable scope to promote more efficient consumption of electricity through changes to building codes, establishment of energy efficiency labelling and mandatory performance standards (MEPS), regulatory or legislative reform to ensure consideration of demand side management in tariff determination, and reform in sectors that consume electricity (such as water supply).

Another significant set of issues is the broader social and economic implications of biomass-based power generation in Fiji. This chapter has argued that a detailed examination of these impacts is necessary, given the broad-ranging effects of diverting land for power generation. Such analysis could also serve to inform the interim government's land reform agenda, and should form the basis for an examination of access rights to biomass resources.

The chapter also argued that the government should explore ways to address the high upfront exploration costs that are preventing development of Fiji's geothermal resources. This might occur through the use of debt guarantees (which could be donor-funded), although this would need to be carefully considered against other budget priorities.

For rural areas not connected to the power grid, chapters five and six demonstrated the financial, social and economic benefits of electrification. Both diesel and solar systems were beneficial, with households of varying income levels demanding different services. The provision of lighting was important for all households, reducing both total energy expenditure and vulnerability of rural households to fuel price volatility.

Government promotion of rural electrification is justified, given the high upfront cost of electrification systems and various market imperfections. The government's objective of ensuring all households are supplied with electricity by the year 2016 is both commendable and *financially* realistic, as assessed by costing in this chapter. The target is nevertheless unlikely to be achieved given present resourcing of rural electrification and the failure to prioritise un-electrified households. Provision of additional funding for rural electrification, with adequate human and financial resourcing of implementing agencies is required.

Also important are measures that ensure installed power generation systems remain operational for their expected lifetimes. Chapters five and six were critical of maintenance arrangements and the one-size-fits-all approach of both the *Rural Electrification Policy* and the *RESCO Program*. The financial sustainability of the *RESCO Program* was also questioned if no explicit subsidy is provided. This chapter has outlined a list of policy recommendations that, if implemented, could help address these issues.

Chapter 8
Conclusion

This chapter provides an overview of the research findings presented in this dissertation. Renewable technologies have been shown by this research to improve energy security in the power sector of Fiji. In the electricity grid, renewable technologies reduce both power generation costs and financial risk from oil price volatility by replacing oil-based power generation. In rural areas not connected to the electricity grid, renewable technologies are a cost effective means of rural electrification, reducing household expenditure on energy by replacing "traditional fuels" used for lighting, such as kerosene. Barriers to the use of renewable technologies exist in both cases. These have been analysed in this thesis along with policy responses. This chapter concludes by pointing to the relevance of these findings to other Pacific island countries and SIDS, and discussing possible directions for future research.

8.1 Overview of Research

8.1.1 Background

Renewable technologies have been advocated in recent years in the electricity sectors of Fiji and other SIDS as a response to oil price volatility. Such arguments, commonly framed in terms of energy security, follow record high oil prices in recent years, which have had detrimental economic and social impacts on SIDS in the Pacific. High oil prices have also threatened energy security in the power sectors of Pacific island countries.

Despite widespread support for the use of renewable technologies to reduce vulnerability to oil price volatility and thereby improve energy security, there has been little research on the impact of renewable technologies on energy security in Fiji and other Pacific island countries. This research has addressed these gaps in knowledge.

8.1.2 Research Approaches

This dissertation has developed and applied different approaches in order to assess energy security in the electricity grid and in rural areas not connected to the grid (off-grid areas).

In the electricity grid, a stochastic simulation model of power generation, based on portfolio theory, has been used to assess renewable technologies on the basis of their impact on expected average generation costs and financial risk. The model also accounts for variability in output from renewable technologies in order to better reflect the reliability constraints present in an isolated island system like Fiji's electricity grid.

In rural areas not connected to the electricity grid, data on the length and underlying reasons for power outages has been used to quantify threats to energy security in off-grid electrification systems. Household expenditure on energy was also assessed, given the common substitution of "traditional" fuels such as kerosene for electricity.

The impact of institutions on renewable technology investment and energy security was also explored in this dissertation.

8.2 Findings: The Electricity Grid

Energy security in Fiji's electricity grid over the medium- to long-term is best understood in financial terms (see chapter two). The principal threat to energy security in the grid is price-based, with increases in power generation costs placing upward pressure on prices, and potentially affecting the finances of power utilities and governments.

8.2.1 Modelling Results

Portfolio theory was applied to Fiji's electricity sector in chapter three, enabling assessment of the generation cost and financial risk implications of investment in different renewable technologies. The modelling results broadly support forecast investment in grid-based renewable technologies in Fiji looking forward to 2025. Power generation portfolios with high levels of renewable technology penetration feature lower generation costs and levels of financial risk than do portfolios with minimal renewable technology penetration. These results are valid despite the need in the case of many renewables for back-up oil-based power generation capacity to ensure reliability of supply. The results can be explained by diversification, as the cost streams of renewable technologies are neither correlated with those of oil-based power generation, nor with one another.

However, the results also indicate that low-cost, low-risk technologies such as geothermal, biomass and bagasse-based power generation reduce financial risk and (especially) generation costs to a greater extent than does hydro-power generation. This suggests the Fiji Electricity Authority's (FEA) prioritisation of hydro-power investment over investment in other renewable technologies is, from an economic perspective and bearing in mind the limitations of the model, mistaken. The results also suggest that energy efficiency measures are likely to considerably reduce financial risk and generation costs, and that demand side management warrants more attention from government.

8.2.2 Institutional Arrangements and Reform

At the institutional level, policy reform in the last 10 years is facilitating investment in grid-based renewable technologies in Fiji (see chapter four). Tariff reform in particular is promising. The government has established an independent multi-sector regulator, the Commerce Commission, which is responsible for setting electricity prices for the grid. In recent years, the Commerce Commission has significantly increased tariff rates, so that they reflect power generation costs and enable FEA investment in renewable technologies (which should result in lower electricity prices in the long run). The Commerce

Commission has also set minimum feed-in tariff rates for Independent Power Producers (IPPs). This move should attract IPP investment in the long run, and addresses a significant barrier to IPP investment in the past: the monopsony position of the FEA.

One problem with tariff determination to date has been that it does not provide the FEA or IPPs with incentives to promote demand side management. The dissertation has discussed a number of options available to government to address this problem (see below).

Another problem with tariff determination has been its goal of ensuring that tariffs reflect electricity generation costs. "Rate of return" regulation potentially reduces the incentives of a utility to lower costs, given that it is guaranteed a return on its investment. In Fiji, rate of return regulation is one reason that the FEA has prioritised hydro-power investment, as it is guaranteed a return on long term investments with high upfront capital costs. Other reasons include managerial experience with the technology, and perceived complexity of power generation in other sectors given the involvement of multiple stakeholders (examples are seen in the sugar or timber industries). This issue could potentially be addressed by a move towards price cap regulation, where tariffs are set for periods of time enabling a utility to profit from efficiency gains. Recent statements by the Commerce Commission may signal a move towards price cap regulation, although this is not yet certain.

New electricity reforms were announced by the government in 2011, but are yet to be implemented. These reforms include the partial privatisation of the FEA, which will remain under government control, and the movement of certain regulatory functions to other government bodies. The movement of regulatory responsibilities away from the FEA is a positive move. However, the partial privatisation of the FEA appears to be driven primarily by the fiscal problems of the present government, and may not result in significant changes to the way the FEA operates. The move is likely to also mean the government no longer provides the FEA with debt guarantees, and may inadvertently raise debt financing costs for grid-based renewable-power investments. Complete liberalisation of Fiji's electricity grid is in any case unlikely, given the limited scope for competition and the economies of scale present in the small-scale grid.

8.2.3 Addressing Barriers to Renewable Technology Investment: Some Policy Options

Access to finance remains the principal barrier to investment in grid-based renewable technologies by IPPs (as discussed in chapter seven). It is also likely to become more problematic for the FEA once the partial privatisation process is complete. Investment in Fiji is perceived as risky among foreign investors given political instability and its consequences for regulatory uncertainty, which chapter four shows are significant. There are limited options available to the Government of Fiji in addressing this issue. The most effective strategy in the long run is to reduce perceived risk in Fiji through effective and stable regulation in the power sector, and by increasing political stability. An end to military rule and reconciliation between the various political groups would greatly reduce perceived risk and increase confidence in Fiji's economy.

An end to military rule would have the added benefit of making available finance from "traditional donors" that have halted development assistance as a result of the coup. Financing from donors could be a significant component of future investment in grid-based renewable technologies in Fiji. International carbon financing arrangements, although yet to be determined, may also prove a future source of financing for renewable technologies.

Access to donor financing could be especially important for development of geothermal-based power generation. Development of "low-cost, low-risk" geothermal-power production capacity has been hindered to date by the high upfront exploratory costs involved. Donor money could play an important role in facilitating exploration of geothermal resources. Research on other key renewable energy resources is also needed. The Fiji Department of Energy is currently undertaking such research on wind, solar and various other renewable energy resources.

Limited access to renewable energy resources is another barrier to investment by IPPs in Fiji's electricity grid, as discussed in chapter seven. In the sugar industry, the Fiji Sugar Corporation retains its monopoly on purchases of sugar cane, limiting investment in bagasse-based power generation by other IPPs. In the timber industry, Tropik Wood and its parents company, Fiji Pine Limited, control the majority of forestry in Fiji, limiting access to biomass in the timber industry by other IPPs.

Production of low-cost, low-risk power from biomass is nevertheless complex. There are trade-offs in the use of agricultural resources for food and biofuel production. Studies are needed on the broad-ranging impacts of using agricultural land for biomass-based electricity generation in Fiji. Addressing the issue of access to biomass and bagasse energy resources is also related to politically sensitive questions of land tenure. It is recommended in chapter seven that the government considers access to renewable energy resources in its broader attempts to reform land tenure arrangements.

Electricity production from bagasse ultimately depends on the survival of the sugar industry. The poor performance of the sugar industry in recent years is the result of the removal of EU subsidies, expiry of land tenure leases, and inefficiencies in the Fiji Sugar Corporation. Government attempts to both reform land tenure arrangements and implement changes in the Fiji Sugar Corporation will be critical in ensuring the continuation and expansion of power generation in the sugar industry. It is too early to judge whether measures implemented to date have been a success.

Existing institutional arrangements in the electricity sector have failed to facilitate investment in energy efficiency measures. Electricity generators have no commercial incentive under current arrangements to promote demand side management. The government should address this using various strategies. One strategy involves implementation of energy labelling and minimum energy performance standards. The modelling presented in this dissertation suggests that implementation of these measures would significantly reduce average generation costs and financial risk in the electricity grid through displacement of oil-based power generation.

A number of other strategies should also be considered (although their impact has not been modelled in this dissertation due to insufficient data). Improvement of building codes could lead to more efficient power consumption over the long-term. Reform in other sectors, such as water supply, could also reduce power consumption. The government can also encourage the FEA and IPPs to promote demand side management more rigorously through regulatory or legislative reform. These reforms are wide-ranging and will therefore require a whole-of-government approach.

8.3 Findings: Rural Off-Grid Areas

Energy security in rural areas not connected to the electricity grid (off-grid areas) needs to be considered differently from grid-connected areas, given the common substitution of "traditional" fuels such as kerosene for electricity. Threats to energy security in off-grid areas are both price and supply-based, as outlined in chapter two. Oil price volatility increases the cost of energy for rural households, potentially affecting oil-based power generation and forcing households down the "energy ladder". At the same time, power outages in off-grid electrification systems are common.

8.3.1 Fieldwork Results

Energy security in rural off-grid areas was assessed in chapter five through analysis of power outages and household energy expenditure. Fieldwork involving a survey, interviews and focus group discussions was used to collect this data in four rural communities, where households are un-electrified or use solar and diesel electrification technologies.

Results demonstrate significant increases in household expenditure on energy as a result of oil price increases. Average household expenditure on energy increased approximately 70 to 90 per cent between 2004 and 2008. As a result, energy expenditure comprised around one-quarter of households income among indigenous Fijian households in 2008. Interview and focus group discussions suggest that there was consequently a decrease in energy consumption and movement down the "energy ladder".

Oil price volatility had varying impacts on different household groups. Un-electrified households were found to spend significantly more on energy than electrified households. This result confirms financial arguments in support of rural electrification, which suggest electrification decreases energy expenditure for essential services such as lighting. Increases in energy expenditure resulting from oil price rises were also highest among un-electrified households, both in relative and absolute terms.

Energy expenditure was lowest among households connected to a solar photovoltaic lighting system. Households with a solar system were also affected less by increases in oil prices when compared to un-electrified households and households connected to a diesel generator. This is mainly the result of the replacement of "traditional" lighting fuels such as kerosene, with electricity from solar systems. Diesel systems were not as effective in this respect, as they only provide electricity (and lighting) for several hours each night in the surveyed communities.

Fieldwork results suggest that electrification reduces fuel consumption, thereby producing real energy security benefits for rural households. In the surveyed communities, reduced fuel consumption is most pronounced when solar systems are employed.

Despite these findings, power generation in off-grid areas was found by the survey to be highly unreliable. Power outages were common among both solar and diesel systems. For solar systems, the main causes of power outages were technical problems, which resulted from failures to provide adequate maintenance to installed systems. For village diesel generators, technical problems were also a common cause of power outages. More significant still however, was the inability of villages to collect sufficient money to purchase fuel to operate the generator. The failure to collect money also caused delays in repairs to generators, prolonging power outages caused by technical problems.

8.3.2 Institutional arrangements for rural electrification

The reasons for power outages among both solar and diesel off-grid electrification systems are to be found at the institutional level, as detailed in chapter six. Solar systems surveyed for this research are installed under the *Renewable Energy Service Company (RESCO) Program*. Households pay a monthly fee for their solar system to the Department of Energy, which contracts a private sector company (a RESCO) to conduct maintenance and ensure systems are operational. Information asymmetries between the Department of Energy and the RESCO create principal-agent problems, as the RESCO is paid regardless of whether it provides maintenance to installed solar systems. The RESCO therefore has limited financial incentives under the *RESCO Program* to perform its functions adequately.

Staff members in both the RESCO and Department of Energy also face motivational problems due to information asymmetries. For the RESCO, monitoring the provision of maintenance is difficult for management given the remoteness of installed systems. Fieldwork data revealed that maintenance was commonly not performed adequately, despite visits by RESCO staff to rural communities. For the Department of Energy, delays in the supply of spare parts for solar systems (which the Department is responsible for) can likewise be attributed to motivational problems, although also important are staff shortages and tendering procedures that the Department is obliged to follow. These issues result in poor maintenance of installed solar systems.

Village diesel systems are installed under the government's *Rural Electrification Policy*, which provides households with a 95 per cent subsidy on the upfront cost of the system. The generator becomes the property of the village, which is responsible for its operation and maintenance. Institutional arrangements at the village level are therefore important for understanding the performance of diesel generators. Electricity provision at the village level has common good features, as consumption is non-excludable. This is the result of social norms in the village, which dictate that all households receive power regardless of whether they pay for fuel to operate the generator.

The most common reason for power outages in village diesel systems is that insufficient funds are collected to purchase fuel for the generator. This is the result of the non-excludability of electricity supply. Technical problems are also prolonged as collection of sufficient funds for repairs can take time. Nevertheless, collection of money is more successful than economic theory relating to non-excludable goods would suggest, given strong social norms under the *kerekere* system. This means that electricity is generally available in the hours it is supposed to be supplied, regardless of its non-excludability under village social arrangements.

8.3.3 Policy Implications for Rural Electrification

Fieldwork results demonstrated the financial, economic and social benefits of rural electrification. The government objective of ensuring that all households in Fiji are electrified by the year 2016 was also shown in chapter seven to be feasible. Government assistance will be required if this is to occur, given the high upfront cost of electrification, and a lack of information about electrification technologies in rural areas (particularly in relation to renewable technologies) (see chapter seven for a discussion). Approximately 11 per cent of households in Fiji had no electricity supply in 2007, according to census data. The majority are likely to reside in areas distant from the electricity grid. The cost of electrification of these households can be met by the Fiji Government if it considers its electrification objective to be a priority. However, current funding and policies for rural electrification are inadequate.

The analysis in chapter seven demonstrated that an annual budget for rural electrification of between FJ$15 million and FJ$18 million is required for all households in Fiji to be electrified by 2016 under current electrification arrangements. Government funding will therefore need to appreciably increase above current levels, which amounted to FJ$6 million in 2010. Funding required to meet the government's target could be significantly reduced if un-electrified households, which now account for 46 per cent of beneficiaries of rural electrification policies, were prioritised (improving the electricity supply of electrified households forms a significant part of the rural electrification program, as outlined in chapter seven).

Rural electrification policies also need to be reformed for electrification of households to be sustainable. The installation of electrification systems that stop functioning after only several years due to poor maintenance is costly. A number of measures discussed in chapters six and seven could help address the issue of sustainability.

Rural electrification policies should better consider the needs of rural households. The "one-size-fits-all" approach of the *RESCO Program* should therefore be replaced, with households offered electrification systems that provide different services at different prices. For diesel generators, installation of household batteries that enable the use of power for lighting at any time of the night would greatly increase the economic, financial and social benefits of electrification.

The government should also consider the impact of funding arrangements on technology choice when formulating rural electrification policy. Currently, low fees under the *RESCO Program* encourage rural households to opt for solar technology. This support for solar technology is not official government policy. Fees charged to households should also be reviewed on the basis of their affordability and impact on program sustainability. The fee structure of the *RESCO Program* does not presently cover the costs of maintenance. Such subsidies should be made explicit. Necessary funding should also be made available to the Department of Energy in order to ensure satisfactory program implementation.

A number of changes could help improve maintenance provided under the *RESCO Program*. Principal-agent problems could be addressed by better linking RESCO revenue with system performance, through having the RESCO collect money from households. Delays in Department of Energy procurement of spare parts could be addressed by moving responsibility for this role to the RESCO. Oversight of RESCO activities could be improved by the introduction of a formal complaints mechanism by the Department of Energy.

Improving maintenance and operation of diesel generators is more difficult, given community operation, maintenance, and ownership of generators installed under the *Rural Electrification Policy*. Chapter seven suggested the establishment of "sustainability funds" by electrification beneficiaries in order to pay for maintenance; which could include government co-contributions to encourage deposits. Similarly, the removal of the 3-year grace period currently provided in the *Rural Electrification Policy*, which contributes to community dependence on government, could improve community maintenance of generators. Lastly, education and training need to be improved in order to better prepare communities for operation and (basic) maintenance of a generator.

8.4 Relevance of Research Findings and Areas for Further Study

The methods used in this dissertation can be applied in the context of other Pacific island countries and SIDS. Many of the findings of this research are also relevant to these countries. The application of portfolio theory to the electricity grid provides a means of assessing investments in power generation technologies on the basis of both generation cost and financial risk. Significantly, the model developed in this dissertation accounts for the intermittency of renewable technologies. This is important in ensuring reliability of supply in isolated systems, such as those in Pacific island countries and SIDS. The application of similar models to other SIDS could provide a better understanding of the benefits of renewable technologies in the power sector of such countries. There is also scope for future research on the applicability of portfolio theory to the energy sector of SIDS more broadly; research that could provide an overview of the impact of investments on energy security at the national level.

The need for further research on renewable energy resources and energy efficiency in Fiji was also identified in this dissertation. Analysis of demand side management policies and their impact is particularly lacking. Similar research priorities exist in other Pacific island countries. Access to applicable renewable energy resources needs to be studied and/or reviewed in many Pacific islands, given customary land ownership and exclusive control of certain resources by state-owned enterprises. Appropriate leasing arrangements should ensure that access to resources for power generation is balanced with the interests of land owners, and does not lead to the alienation of land. Issues such as food and fuel trade-offs associated with biomass-power generation need to be considered in these studies.

Another area for future research is the applicability to Pacific island countries of financing arrangements for power sector investment used elsewhere in the world. An overview of some options was discussed in chapter seven, but without a comprehensive study of financing arrangements at the level of the firm. Future research could also assess the use of international carbon financing arrangements in the Pacific islands, once those arrangements are determined.

Results from rural fieldwork presented in this dissertation are relevant to other Pacific island countries. The financial impact of high fuel prices on rural households not connected to the power grid is likely to be similar across Pacific islands, as are the benefits of rural electrification.

The analysis of rural electrification policies in Fiji is not directly relevant to other jurisdictions, but does nonetheless provide lessons that are applicable across countries. The dissertation shows that effective rural electrification policy needs to consider the sustainability of installed systems. This means a focus on incentives for system operation and maintenance. Education and training is also important, especially where operation and maintenance occurs at the community or household level. Rural electrification policy should also ensure that installed systems meet the needs of households, consider the impact of financing arrangements on technology choice, and provide adequate resources to implementing agencies. Studies of rural electrification policies and their effectiveness will inevitably remain context-specific.

The analysis of the *RESCO Program* in this dissertation also shows that private sector involvement is no panacea to problems experienced with public sector maintenance of electrification systems. For private sector involvement to be beneficial, institutional arrangements need to ensure that incentives are established for private sector entities to perform the roles required of them. Incentive alignment is especially important considering the remoteness of un-electrified households, limited resources among government rural electrification authorities, and resulting information asymmetries in Pacific island countries.

There is scope for further research on institutional arrangements that both meet the requirements for rural electrification policy outlined above, and are appropriate in a Pacific island/SIDS context.

8.5 Finally: A Word on Governance

The dissertation has shown that there is a role for renewable technologies in improving energy security in Fiji's electricity sector. In the electricity grid, investment in "low-cost, low risk" technologies, including energy efficiency measures, reduces both financial risk and generation costs in the model. In rural areas not connected to the power grid, rural electrification lowers expenditure on energy and reduces exposure to oil price volatility, with impacts most pronounced when power for lighting is available at any time (such as with solar systems).

It is unlikely that the Fiji Government will achieve its ambitious renewable energy or rural electrification targets by 2015-16. Significant investment in renewable technologies is nevertheless occurring, spurred by higher tariff rates and effective independent regulation. All households across Fiji should have an electricity supply by around 2020-25 if current funding for electrification continues.

However, progress ultimately depends on effective and stable governance. Access to international finance and donor funding will be important in achieving the government's renewable technology objectives. An effective regulatory environment is needed for both sources of funding, and for better demand side management. The establishment of a stable and representative democracy, not dominated by special interest groups or race-based politics, will help in the establishment of sound regulation, and will also facilitate investment and economic growth in Fiji. Continued conflict and political instability will have the opposite effect.

Effective governance is also important for rural electrification policy. Political instability (now and in the past) has adversely affected the public service in Fiji, with migration of skilled professionals overseas, and appointment of managers on a political rather than merit basis. Rural electrification is complex, and sound policy requires a strong and capable civil service. To this end, government needs to become more transparent and accountable. Establishment of a stable and representative democracy again can assist in achieving these goals.

Appendix

A1.1 A Partial List of People Interviewed for this Research

**This list does not include the large number of people interviewed in the communities of Dama, Wairiki, Nakawakawa or Vunivao*

<u>Department of Energy</u>
Pecelli Nakavulevu – Director, Department of Energy
Inia Saula – Principal Science Officer
Paula Katirewa – Principal Science Officer
Moape Waqa – Information Officer
Susana Pulini Principal Science Officer
Vilimone Vosarogo – Head of Biofuels Unit
Deepak Chand Science Officer
Apenisa – Solar Technician
Makareta Sauturaga – Former Director, Department of Energy

<u>Rural Electrification Unit</u>
Jimione Aperto – Director, Rural Electrification Unit
Frank Rokowaqa – Senior Technician
Viliame Silatolu – Technician
Asivorosi Raileqe – Technician
Jope Caginibua – Technician
Iliesa - Driver

<u>Public Works Department</u>
Semi Kedrawaca – Manager, Generation

<u>Ministry of National Planning and Finance</u> (prior to their division)
Kamal Gounder, Economic Planning Officer, Energy

Provincial Government (Bua)

Ratu Orisi Baleitavea – Tui Wainunu

Jese – Bua District Officer

Epeli – Tikina representative (Wainunu)

Partab Chand – President of Vunivao Solar Committee, Former Advisory Councillor to the Provincial Council

Commerce Commission

Dr Mahendra Reddy – Chair

Prices and Incomes Board

Satish Chand – Manager, Labasa Office

Aten Kumar – Labasa office

Fiji Electricity Authority

John O'Connor – Manager, Human Resources

Fatiaki Gibson – Manager, Generation

Fiji Bureau of Statistics

Prakash Chand – Information Officer

Consumer Council of Fiji

Premila Kumar – Chief Executive Officer

Cegu Babana – Campaigns, Information & Media Officer

Fiji Sugar Corporation (IPP)

C.P.Pillai, Co-generation Manager

Tropik Wood (IPP)

Vimlar Kumar – Chief Financial Officer

Delta Energy (new IPP)

Steve Foley – Chief Executive Officer, Delta Renewable Energy (Fiji) Limited

SEAMECH (potential Fijian IPP)

Ross Brodie – Manager

Geothermal Electric Limited (potential Fijian IPP)

Tim Daniel – Chief Executive Officer

RES Ltd (RESCO in Vanua Levu)

Krishn Raj – Director and Owner

Mahendra Kumar – Former Technician

University of the South Pacific

Dr Anirudh Singh

Dr Atul Raturi

Dr Tony Weir

Dr Sunil Kumar

Dr Peter Stauvermann

Energy Consultants

Peter Johnston

Chris Cheatham

Luis Vega (correspondence)

United Nations Development Programme

Thomas Jensen – Environment and Energy Policy Specialist

Pacific Power Association

Tony Neil – Executive Director, PPA

Gordon Chang – Deputy Executive Director, PPA

Pacific Islands Applied GeoScience Commission

Arieta Gonelevu – Senior Project Officer, Energy

Rupeni Mario – Senior Advisor, Energy

Shakil Kumar – Petroleum Adviser

Reshika Singh – Adviser

Secretariat of the Pacific Community

Hitofumi Abe – SPC/JICA Regional Forestry Advisor (correspondence)

Pacific Islands Forum Secretariat

Scott Hook – Energy Adviser

International Union for the Conservation of Nature

Anare Matakiviti – Oceania Energy Programme Coordinator

Arieta Gonelevu – Project Officer

Asian Development Bank

Anthony Maxwell – Energy Specialist

World Bank

Tendai Gregan – Energy Adviser, Pacific Office

Wendy Hughes – Senior Energy Adviser, Pacific Office

AusAID

Theo Levantis – Economic Adviser

Christine Pahlman – Pacific Section

NZAid

Joseph Mayhew – Renewable Energy and Climate Change Advisor

A2.1 Implications of Peak Oil

The Peak Oil Theory

The peak oil theory was first developed by M. King Hubbert, who posited that mineral resource extraction follows a curve shaped like a normal distribution (i.e., it is symmetrical and bell-shaped). Hubbert used the approach to correctly forecast the peak of oil production in the United States in 1970, although he was wrong about the level of production (Smil 2008). Peak oil theory has subsequently been used to correctly estimate the peak and decline of oil production in Norway and other countries.

Many peak oil theorists predict alarming impacts from the decline of oil production. There are however alternatives to conventional oil. Non-conventional oil has until recently not been included in estimates of oil reserves.[193] Large amounts of heavy fuel oil reside in the Orinoco belt in Venezuela, and an even larger sand oil resource is present in Canada. Production is occurring in both locations, despite higher processing costs. In the case of the Canadian tar sands, reserves are estimated to be in the order of 174 billion barrels of oil; comparable to Saudi Arabia's 260 billion barrels of conventional oil reserves. It is likely that this figure will be revised upwards as production and exploration continues (Smil 2008). There are also vast oil shale reserves in the United States and China, extraction of which is not yet technically or economically viable (although this is likely to change in the future). Coal-to-liquid fuels and the use of natural gas for transportation are also commonly cited as having a role to play in future diversification away from oil (EIA 2010; EIA 2011a; IEA 2010; Smil 2008)

The problem with these alternatives is their environmental impact (with the exception of natural gas). Oil produced from tar sands and heavy fuel oil produce harmful gases such as

[193] This is changing. The U.S Securities and Exchange Commission in 2010 modified its reporting rules, so that unconventional sources of oil, such as heavy crude oil, oil sands, and oil shale, are now considered part of oil reserves where a strip mine or thermal facility for extraction has been established (U.S. Securities and Exchange Commission 2010).

sulphur dioxide, and in the case of tar sands, requires extensive mining. Non-conventional oils also produce greenhouse gas emissions in quantities significantly higher than those produced by the consumption of conventional oil.[194] Peak oil is likely to increase consumption of more harmful alternatives, such as tar sands and coal, with adverse climate change impacts. The UK Energy Research Centre report cautions against such a scenario, arguing that "early investment in low-carbon alternatives to conventional oil is of considerable importance" (Sorrell, et al. 2009: ix).

Timing of Peak Oil

The timing of peak oil has been the subject of heated debate. This is the result of a lack of available data and the large number of "unknowns" that will affect future oil production and consumption. In order to correctly calculate the timing of peak oil, data is required on: cumulative production to date; the amount of oil that can be economically produced from existing wells; and the quantity of oil that remains to be discovered (Campbell and Laherrére 2007; Smil 2008). There is reasonably good information about cumulative production to date. Information about oil reserves is much more unreliable.

Almost all figures on oil reserves come from annual surveys of governments and oil companies conducted by *Oil and Gas Journal* and *World Oil*. The figures provided for these surveys are not verified by the journals. Respondents have incentives to report figures that best suit their interests. For example, the price of an oil company's shares can increase if it exaggerates its estimated reserves. In the case of OPEC, the output of member states is based on the size of their reserves, providing them with strong incentives to over-report (Campbell and Laherrére 2007).[195] Estimating oil reserves is complicated further due to the uncertain nature of "proven reserves" that remain underground.[196]

[194] The issue of climate change is generally sidelined in discussions about peak oil. In an interesting discussion in the *World Energy Outlook* 2010, the IEA discusses the need to peak oil consumption rather than production. The IEA argues that oil consumption needs to peak in 2018 if there is any chance of global average temperatures increasing by less than the 2 degrees Celsius agreed to as part of the Copenhagen Accord (IEA 2010).

[195] There are many examples of inconsistent statistics being provided to *Oil and Gas Journal* and *World Oil*. For example, in the late 1980s, six of the 11 OPEC countries increased their reserves figures by unrealistic amounts, ranging from 42 to 197 per cent (subsequently increasing their export quotas) (Campbell and

The other "unknown" regarding future oil production is demand for oil. Many analysts and geologists incorrectly predicted in the 1970s that oil production would peak before the year 2000. Their estimates failed to consider changes in demand or technical progress. As a result of the oil shocks of the 1970s, oil importing countries implemented energy efficiency and diversification measures. Demand for oil subsequently was lower than had been forecast. Estimates that peak oil would occur before the year 2000 were therefore incorrect (Smil 2006; Smil 2008). Current attempts to predict the timing of a peak in world oil production are difficult for the same reasons. Future technological progress is uncertain and impossible to accurately predict, as are consumer habits, economic activity, and government policies. These influence demand for oil.

The many uncertainties described above have led to debate regarding when peak oil will occur. A majority of analysts now predict that peak oil will be reached before 2030, with many suggesting a peak prior to 2020 (Campbell and Laherrére 2007; IEA 2010; Smil 2006; Sorrell, et al. 2009). Among these estimates is the prediction of the International Energy Agency, which sees production peaking "sometime before 2030", and unless significant new discoveries occur, before 2020. An independent report by the UK Energy Research Centre published in 2009, arrived at a similar conclusion (Sorrell, et al. 2009). Based on a review of over 500 studies, and using industry data, the authors predicted a peak in conventional oil before 2030, with there being a significant risk that oil production will peak before 2020. The report also argued that estimates that put the peaking of world oil production after 2030 were "at best optimistic, and at worst implausible" (Sorrell, et al. 2009: x).

Laherrére 2007). Similarly in 1997, 59 non-OPEC countries claimed that reserves remained unchanged; an outcome which is highly unlikely given the gradual drop of reserves as oil wells are exploited and their sudden increase when new discoveries are made (Campbell and Laherrére 2007).

[196] Estimates are assigned a probability between 90 and 10 per cent certainty that a given level of oil can be extracted. Respondents in the surveys are commonly vague about what probability is referred to in their stated "proven" reserves. The United States uses the 90 per cent benchmark. In other words, the United States Government is 90 per cent certain that it will produce the oil declared as part of its "proven reserves". In the case of the former Soviet Union, exaggerated figures provided in 1996 most likely referred to a 10 percent certainty level. These figures were accepted as "proven reserves" by *World Oil*, which subsequently estimated the Soviet Union's oil reserves to be 190 billion barrels. *Oil and Gas* was more skeptical and put the figure at just 57 billion barrels of oil (Campbell and Laherrére 2007). Such large discrepancies demonstrate the high degree of uncertainty in measuring oil reserves.

A3.1 Generation Costs

Hydro-power

The capital cost of hydro-power projects varies between different projects, as can be seen in table A3.1a.

Table A3.1a Capital Cost of Hydro Projects in Fiji

Hydro-power plant	Initial Capacity (MW)	Capital Cost (FJD/kW)	Initial Capital Cost (nominal millions FJD)	Initial Capital Cost (2009 millions FJD)
Wailoa	80	3,000	240	709
Wainique	0.8	3,125	2.5	5
Wainikasou	6	2,575	15	19
Nagado	1.9	3,000	6	7
TOTAL	88.7	n.a	263.65	739

A3.2 Energy Efficiency Measures in Fiji

Refrigeration

A 2004 study of refrigeration in Fiji found that 75 per cent of all refrigerators and 100 per cent of freezers were imported from Australia and New Zealand (Department of Energy 2004). The implementation of Minimum Energy Performance Standards (MEPS) in Australia and New Zealand has successfully improved the energy efficiency of refrigeration in Fiji as a result. Nevertheless, there is evidence that imports from other geographical areas are often directed towards Pacific islands (including Fiji) because those products can no longer be sold in their place of production (such as in Taiwan, where MEPS have also been introduced).

George Wilkenfeld and Associates Pty Ltd (2011) estimates that if Pacific island countries adopted energy efficiency labelling and MEPS used in Australia and New Zealand for refrigerators and freezers, annual residential electricity consumption would decline by approximately 72 GWh and commercial and government sector consumption by 24 GWh. The corresponding energy savings from labelling and MEPS for refrigerators and freezers in Fiji amount to 20.88 GWh for the residential sector and 6.96 GWh for the commercial and government sector, given that Fiji accounts for 29 per cent of all potential energy efficiency savings in the Pacific islands.

Air Conditioning

Less information is available on air conditioners. George Wilkenfeld and Associates Pty Ltd (2011) estimates that energy savings potential for air conditioners is comparable to refrigerators if energy efficiency labelling and MEPS used in Australia and New Zealand were adopted in Pacific island countries. Again, the main reason for energy savings is the removal of energy inefficient air conditioners currently imported by Pacific island countries that are not compliant with MEPS in other countries. This model assumes energy savings in Fiji of 21.17 GWh per year for the residential sector, and 18.85 GWh for the commercial and government sector. This is calculated using Pacific island-wide data (from GWA 2011) and is based on Fiji having a 29 per cent share of Pacific island-wide energy savings.

Lighting

In recent years the replacement of inefficient incandescent light bulbs with compact fluorescent lamps (CFLs) has been highlighted as an easy, quick and cheap way of reducing electricity demand. Several countries have established measure to promote CFLs in response to electricity shortages, such South Africa and Bangladesh (Sarkar and Singh 2009). CFL's consume approximately 80 per cent less electricity than an incandescent lamp in order to provide the same amount of light. They also have a higher upfront cost. Another increasingly popular replacement for incandescent light bulbs are halogen-filled lamps, which look the same but use 30 per cent less electricity than incandescent light bulbs. Halogen-filled lamps are approximately the same price as an incandescent light bulb. In Australia, halogen-filled lamps are commonly used to replace incandescent light bulbs, which are no longer available (incandescent bulbs are not produced domestically and the importation of incandescent bulbs is prohibited).

Energy saving potential from installation of energy efficient lighting is lower in the Pacific islands than in many other developing countries, due to the prevalence of energy efficient linear fluorescent lamps. Incandescent light bulbs are still used however, and their prohibition would reduce electricity consumption in the Pacific islands. This would effectively work as MEPS, with incandescent light bulbs replaced by halogen-filled light bulbs. At the same time, governments and electricity utilities could promote CFLs, which are more energy efficient than halogen-filled light bulbs, but are also more costly. This would be the equivalent of an energy labelling scheme. Annual energy savings in Fiji from these measures are estimated at 15.08 GWh for the residential sector, and 21.17 GWh for the commercial and government sector, assuming Fiji has a 29 per cent share of Pacific island-wide energy savings modelled in GWA (2011).

A3.3 Discount Rates

An important issue in calculating the levelised cost of electricity is determining an appropriate discount rate. A discount rate is commonly used in cost-benefit analysis to distinguish between benefits and costs that accrue in the present and those that accrue in the future. This recognises that people value present utility differently from future utility, and incomes may be higher in the future than at present. A high discount rate, often the same as the commercial interest rate, is generally used for financial impact assessments of commercial ventures and for investment by individuals. A lower discount rate is generally applied to social investments. The rationale behind this is that from the viewpoint of society the consumption of future generations is as (or close to as) important as that of the current generation. The social discount rate must nevertheless account for differences between future and current income, and as such is very rarely set completely at zero.

Determining the discount rate is especially pertinent to an analysis of electricity generation technologies. Renewable energy technologies generally involve high up-front capital costs and low fuel and maintenance costs. Oil-based electricity generation is the opposite, involving low up-front capital costs but high recurring costs associated with fuel and maintenance. This means that the choice of discount rate has a big impact on the relative cost of each technology. A high discount rate will favour oil generation technologies over renewable technologies whereas a low discount rate will do the opposite (Diesendorf 2007; ESCAP 2005; Liebenthal, et al. 1994; Wade 2005a; Woodruff 2007).

There is a great deal of controversy about what discount rate to use for public sector investment. Some economists argue that discount rates used in cost-benefit analyses should reflect the opportunity cost of capital, regardless of whether the project is social or commercial in nature. Others argue for very low discount rates, or social discount rates, sometimes nearing zero per cent (Pearce, et al. 2006). Both arguments have strong normative aspects, but also have some support from empirical studies of human behaviour. Spending patterns generally suggest that people have fairly high discount rates, as shown by high levels of consumer debt and low savings. In other areas however, people show a great deal of concern for the long term, suggesting low discount rates. This can be seen in human action to address the threat of climate change, which involves immediate costs (or investments) for benefits that will accrue in the very long run.

International financial institutions and national governments use a range of discount rates in practice, reflecting the controversy surrounding the choice of discount rates. What is generally agreed is that the choice of an appropriate discount rate will vary in different settings as a result of various factors, including the opportunity cost of capital, inflation, and risk and uncertainty of the investment (IEA 2005; Woodruff 2007). The International Energy Agency (IEA) and the Organisation of Economic Cooperation and Development (OECD) use discount rates of between 5 and 10 per cent when evaluating energy sector investments (IEA 1991; IEA 2005). The IEA often uses both 5 and 10 per cent as part of its sensitivity analysis, where 5 per cent reflects a social discount rate and 10 per cent reflects a commercial discount rate. The World Bank and ADB adopt higher discount rates for social investments. A recent and comprehensive report by the World Bank on the cost of electricity sector investments used a discount rate of 10 per cent, while the ADB *Guidelines for the Economic Analysis of Projects* recommends the use of discount rates within a 10 to 12 per cent band (ADB 1997; World Bank 2006b). Previous studies of the cost of renewable energy technologies in the Pacific islands have used a discount rate of 10 per cent (Woodruff 2007).

A4.1 Energy Policies of the World Bank and Asian Development Bank (ADB)

Support for liberalisation among international donors has moderated as a result of increasing recognition of the difficulties and risks associated with electricity reform in developing countries. The World Bank and ADB, both strong advocates of power sector liberalisation in the past, now argue for reform on a case-by-case basis (Gratwick and Eberhard 2008). ADB energy policy once considered “unbundling of the mix of generation, transmission and distribution”, “private sector participation” and “competition” in the power sector as a priority (ADB 1995a: 11,30). It is now more cautious in its support for such reforms. The ADB’s 2009 Energy Policy instead states that:

> Private sector participation (and public-private partnerships) will be encouraged to enhance energy sector efficiency through competition, and to increase investable resources, *but not as the end objective of reforms*."… "*privatization will not be the target or the end objective of ADB's sector reform activities; instead, it will be one of the options available to enhance energy sector efficiency and increase investable resources* (ADB 2009a: 4,8) (italics are mine).

The new ADB Energy Policy also acknowledges the "special needs" of Pacific island member countries (ADB 2009a: 4). The ADB and World Bank continue to argue for private sector participation in Pacific island countries, but in the form of contracting functions to the private sector and introducing Independent Power Producers (ADB 2008; ADB 2010; World Bank 2006a). This is similar to the monopsony model of power sector regulation. Complete liberalisation of the electricity sector through unbundling of generation, transmission and distribution functions is no longer advocated in the region.

A4.2 Failed Reform of the Civil Aviation Authority of Fiji and the Government Shipyard and Public Slipways

The failed reform of the Civil Aviation Authority of Fiji and the Government Shipyard and Public Slipways has been the subject of previous research (McMaster 2001; Narayan 2005; Narayan 2010). In the case of the Civil Aviation Authority of Fiji, the separation of its commercial and statutory functions resulted in the dismissal of approximately 400 employees and a protracted industrial dispute with the Fiji Public Service Association, the relevant trade union. The dispute was only resolved when the Fiji Labour Party government forced the newly formed organisations to re-hire dismissed employees (Hook 2009; Sarkar and Singh 2009).

The partial privatisation of the Government Shipyard and Public Slipways in 1996 suffered more serious problems. The government did not perform proper due diligence of the private sector entity that purchased a 51 per cent stake in the Government Shipyard and Public Slipways (MCI Carpenters Limited and its New Zealand-based parent company, MCI Group). MCI Carpenters Limited claimed at the time that its parent company, MCI Group, had purchased similar slipways in New Zealand. That claim was later found to be false, with MCI Group having been established only one year earlier, and after the government had announced its intentions to privatise the Government Shipyard and Public Slipways (Narayan 2005; Narayan 2010).

In 1997, MCI Group went into receivership and soon after, MCI Carpenters Limited defaulted on its payment to the government. The Government Shipyard and Public Slipways suffered financial difficulties for two more years, before itself going bankrupt in 1999. The government subsequently repurchased the shipyard and slipways for a higher price than it had received for their sale. It did so on the grounds that the shipyard and slipways were of strategic importance to Fiji and that the government had a social responsibility to the workers that had been affected by the privatisation (McMaster 2001; Narayan 2005; Narayan 2010).

A4.3 The Lack of Public Support or Political Consensus for Public Enterprise Reform

Public enterprise reform in Fiji needs to be understood in relation to the broader political framework in Fiji. Political debate in Fiji has been polarised on the basis of ethnicity ever since independence. This has prevented substantive debate on policy issues and led to rent seeking behaviour in the political sphere (Reddy, et al. 2004).

Public enterprise reform in the 1990s in Fiji had the support of the indigenous political establishment (although not population), but was opposed by Indo-Fijian parties and trade unions. There was similarly a lack of broad-based public support for the reforms, which were designed with significant input from the multilateral banks, but with little input from civil society stakeholders (Dubsky and Pathak 2001; Prasad and Tisdell 2006; Sharma 2009). Reforms also lacked the support of the public service in some instances, particularly where they conflicted with existing interests (Lawrence and Sharma 2010). The lack of a political consensus, along with political instability, explains the slow progress of reform and policy reversals in Fiji – both in relation to public enterprise reform and the broader liberalisation agenda (Dubsky and Pathak 2001; McMaster 2001; Narayan 2005; Narayan 2010; Prasad and Tisdell 2006; Reddy, et al. 2004; Sarker and Pathak 2003).

A5.1 Existing Data and Gaps in Research

Some data already exist on energy use and supply in rural areas of Fiji. However, there is very little data available that relates specifically to energy security, and much of the information that is available is anecdotal in nature. For example, it is common knowledge in the Department of Energy that village diesel generators are operated for only several hours each evening in rural areas of Fiji and that power outages are frequent.[197] Department of Energy staff members also note that high fuel prices in recent years have meant that rural communities are more likely to install solar systems than diesel generators, and made communities more isolated by limiting public transport options, with reduced frequency of boat and bus services (Interviews with Department of Energy staff, July and August 2009).

Census and Household Income and Expenditure Data

General data on rural electrification rates and ownership of appliances are contained in the 2007 Fiji Census (Fiji Islands Bureau of Statistics 2007) and the 2002-03 *Household Income and Expenditure Survey* (Narsey 2006). Neither data source presents information that is specific to Bua province (the area surveyed as part of the research presented here), nor do they adequately describe spending on energy, the impact of high oil prices on households, or threats to energy security.

[197] Such observations are sometimes recorded in written documents, such as in the 2003 *Review of Fiji's Rural Electrification Policy*, which notes that most villages with diesel generators only operate them for between 4 and 5 hours a day and use them mainly for lighting. The same report also notes that power outages are frequent (Matakiviti and Pham 2003).

Energy Use Survey

The Department of Energy has administered several surveys in the last decade. The 2002-03 *Energy Use Survey* aimed to gauge the willingness of rural households to pay for electricity for lighting, and to assess the number of households that might potentially be serviced with a SHS (Namoumou 2003).[198] The *Energy Use Survey* produced some good data on household spending on energy that are referred to in Appendix A5.9. A total of 89 communities from across Fiji were surveyed, with 59 of these being un-electrified and 31 being connected to an off-grid electrification scheme (mainly village based diesel generators).

Rural Electrification Survey

The most comprehensive and important survey administered by the Department of Energy to date is the 2005 *Rural Electrification Survey* (Department of Energy 2006b).[199] The survey had as its goal investigating "actual uses, impacts and operation and maintenance problems of rural and remote power electrification" in Fiji, and asked questions relating to the use of electricity and other forms of energy, economic and social impacts of electricity on rural households, and maintenance and operation of electricity systems.

Some of these results are used to create time series data in this chapter, allowing for a comparison of household answers before and after the oil price spike of 2008. This is possible because the current research project was able to survey many of the same households surveyed in 2005 and compare answers in the two periods. Three of the four communities surveyed in this research project were selected in part because they had been

[198] This survey was funded under the GEF/UNDP RESCO project, which aimed to engage the private sector in maintenance and provision of solar home systems in rural areas.

[199] The survey was funded with money from UNESCAP and UNESCO. Administration of the survey was extensive, with 2,387 households in 74 rural communities included in the survey. Of these communities, 33 (including 958 households) had access to the electricity grid through FEA grid extensions, 37 (including 1,201 households) had village-based mini-grid diesel generators installed by the Department of Energy under the *Rural Electrification Policy*, and four (including 228 households) had solar systems installed under the *RESCO program*. A notable absence in the survey was rural households without access to electricity.

included in the 2005 survey.[200] There were however problems with some of the survey questions. Those relating to the quality of electricity supply, and especially to the frequency and duration of power outages were poorly worded (see below). This limited the usefulness of the survey data, especially that relating to security of electricity supply.

Literature on the RESCO Program and on Communities in Bua Province

The following research has taken place on the *RESCO Program* or Bua province (the areas surveyed as part of the research presented here).

a. Socioeconomic survey of households in Bua province

The Government of Fiji (2005) conducted a small survey of households situated along the Nabouwalu Road in 2005, as part of an ADB funded project determining the impact of the road's expansion on the area. Three of the four communities surveyed as part of the research presented here are situated within 1-2 kilometres of this road (the exemption being Nakawakawa, which is in the south-east of Bua province). The data collected largely relate to incomes and livelihoods of the two ethnic groups in Bua province.

b. Survey of households involved in the *RESCO Program*

Tania Urmee (2009) completed a survey in August 2007 as part of a PhD in Electrical Engineering at Murdoch University. She surveyed 100 households in four communities in Vanua Levu to assess the success of the *RESCO Program* and the impact of SHS on rural households. These communities included Vusasivu, Korokandi, Drikiniwi and Driti, only one of which (Driti) was an indigenous Fijian community. Data collected by Urmee generally confirm the findings of the research presented here.

[200] The fourth community, Nakawakawa, was not included in the 2005 survey.

c. Study of communities involved in the *RESCO Program* (Gonelevu 2006)

Another study on the *RESCO Program* in Fiji was completed by Arieta Gonelevu, a former staff member at the Department of Energy. It formed part of a Masters in Engineering completed in 2006 at Murdoch University. The study involved interviews in 12 communities across Vanua Levu that had SHS installed as part of the *RESCO Program*. Two communities with solar systems surveyed as part of her research are examined in this chapter (Nakawakawa and Vunivao). This helps place my survey results in context.

Gaps in Research

Data from the sources described above were not considered sufficient to explore the key questions raised by this research. The data are used only to contextualise survey data collected for this research project and to provide time series data where possible. Existing data on energy security issues in particular were lacking. Quantitative data on the security of electricity supply and comparisons among different technologies were available only from the 2005 *Rural Electrification Survey*, but these data were poor as a result of badly worded questions (see below). Another problem was that existing data were collected prior to the oil price spike, meaning that the impact of high fuel prices could not be analysed. Data on energy consumption and expenditure were only available for 2002-03. Data for 2007 are available from Urmee (2009), but these data are inconsistent and therefore unreliable (see below).[201] Data from the 2008-09 HIES are yet to be released.

Institutional arrangements for maintenance, fee collection and operation of electricity generation technologies were also not analysed in any depth by Department of Energy surveys. These arrangements are important in off-grid areas due to the significant impact of technical problems on the security of electricity supply. The analysis of institutional arrangements for the *RESCO Program* by two previous research projects was better, although the significant deterioration of systems installed under the program between 2007 and 2009 was not recorded in these pre-2008 studies. In addition, the two previous research

[201] These data were not available at the time fieldwork was conducted, being published in 2010.

projects did not include communities with diesel generators, preventing direct comparison of the two technologies.

Problems with Past Surveys

There were problems with some of the survey questions and answers in existing literature. In the case of Urmee (2009), potentially useful data on household spending on energy were inconsistent, with the proportion of households spending different amounts on energy each month summing to 109 per cent. That survey also reported that prior to the installation of SHS, households spent an average of A$17.63 (FJ$22.04) and a median of A$13.04 (FJ$16.30) per month on kerosene for lighting. However no figures for spending after installation were available, lessening the usefulness of the data for my research.

Wording problems were present in the 2005 *Rural Electrification Survey*, and were particularly serious in questions relating to the security of electricity supply. For example, households were asked to select from multiple choice answers with two parts when questioned about their opinion of services provided by electricity. The five answers available included: (a) “excellent and affordable”, (b) “good, more power needed but cannot afford”, (c) “fair, but more power needed”, (d) “not good, do not like”, and (e) “works ok but price is too high”. The poor wording means that it is not clear which part of the answer respondents agreed with, or whether they agreed with more than one of the answers (they could only select one option).

Other problems with survey questions became apparent only when some of the same survey questions were used for this research project, with the aim of developing time series data. For example, surveyed households were asked:

How often does the power go off when it is supposed to be on? (please tick)

Several times a week	
Maybe once a week	
About once a fortnight	
Probably once a month	
Less than once a month	

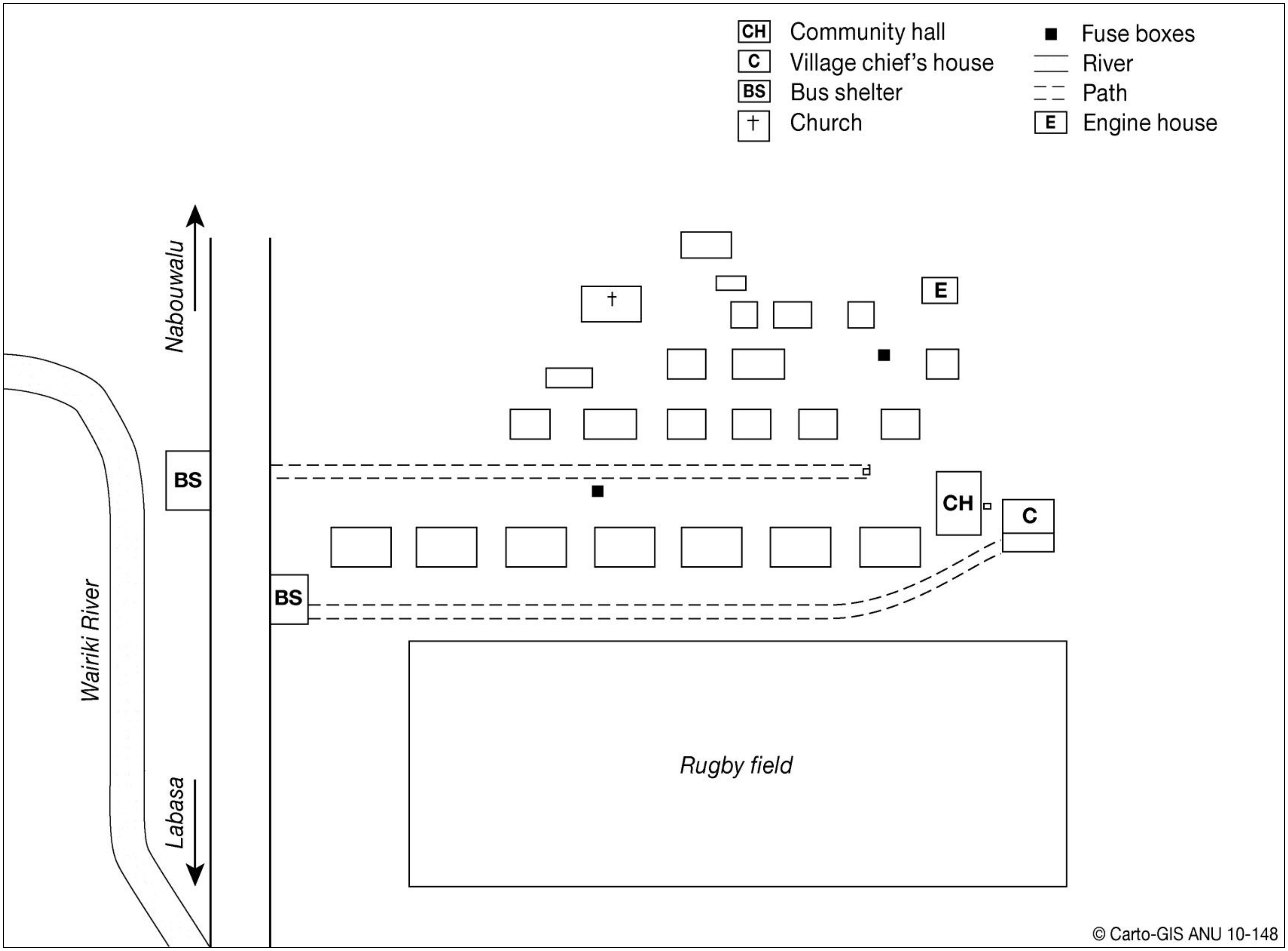
How long does it usually stay off ? (please tick)

Short time (less than 10min)	
Maybe half an hour	
An hour or two	
A day or two	
A week or more	

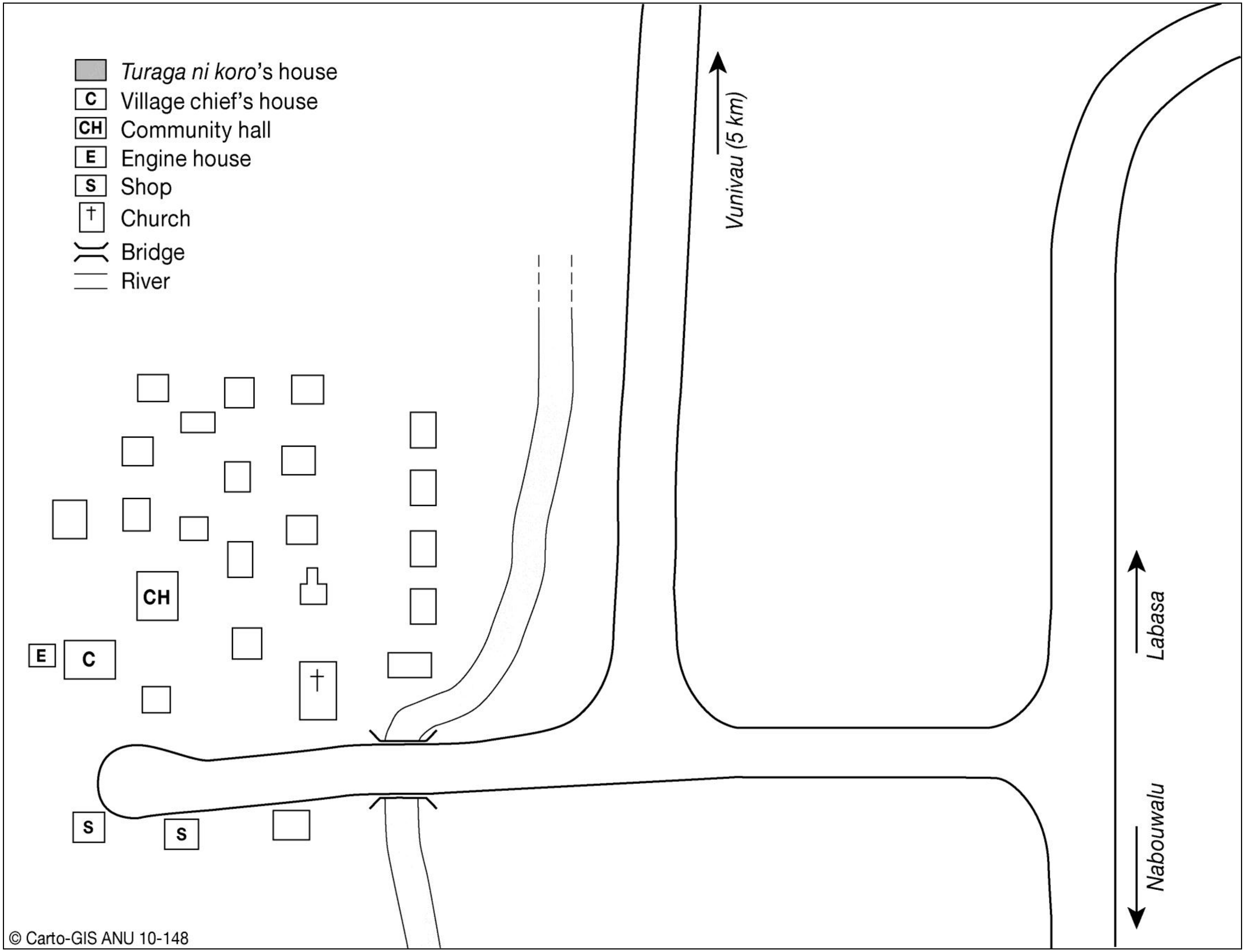
These questions had also been asked in the 2005 *Rural Electrification Survey*. In administering the survey, it soon became apparent that many survey respondents were not satisfied with the options available to them. In the case of diesel generators in Dama and Wairiki, both suffered power outages several times a week as they were overloaded. These blackouts would last for less than half an hour. Approximately once a year, the generators would suffer a more serious technical problem, which would leave them non-operational for over a month. Residents were more concerned about times that the generator was non-operational for extended periods of time. The fact that there were two types of power outages meant that respondents were confused about which answer to select and that results were inconsistent. In addition, the "week or more" option did not adequately reflect the duration of long power outages, which lasted for over a month.

A5.2 Maps of Surveyed Communities

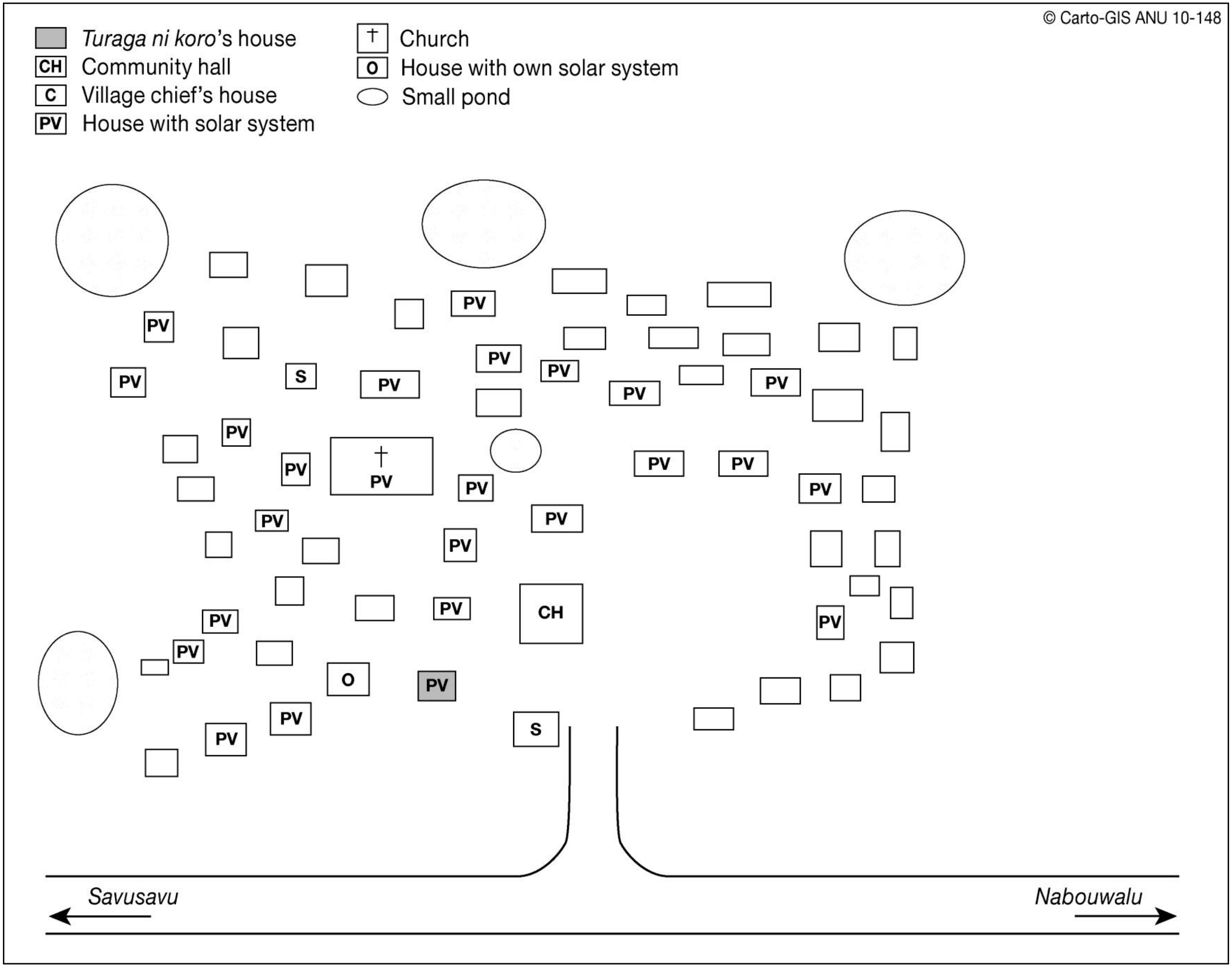
Map of Wairiki village



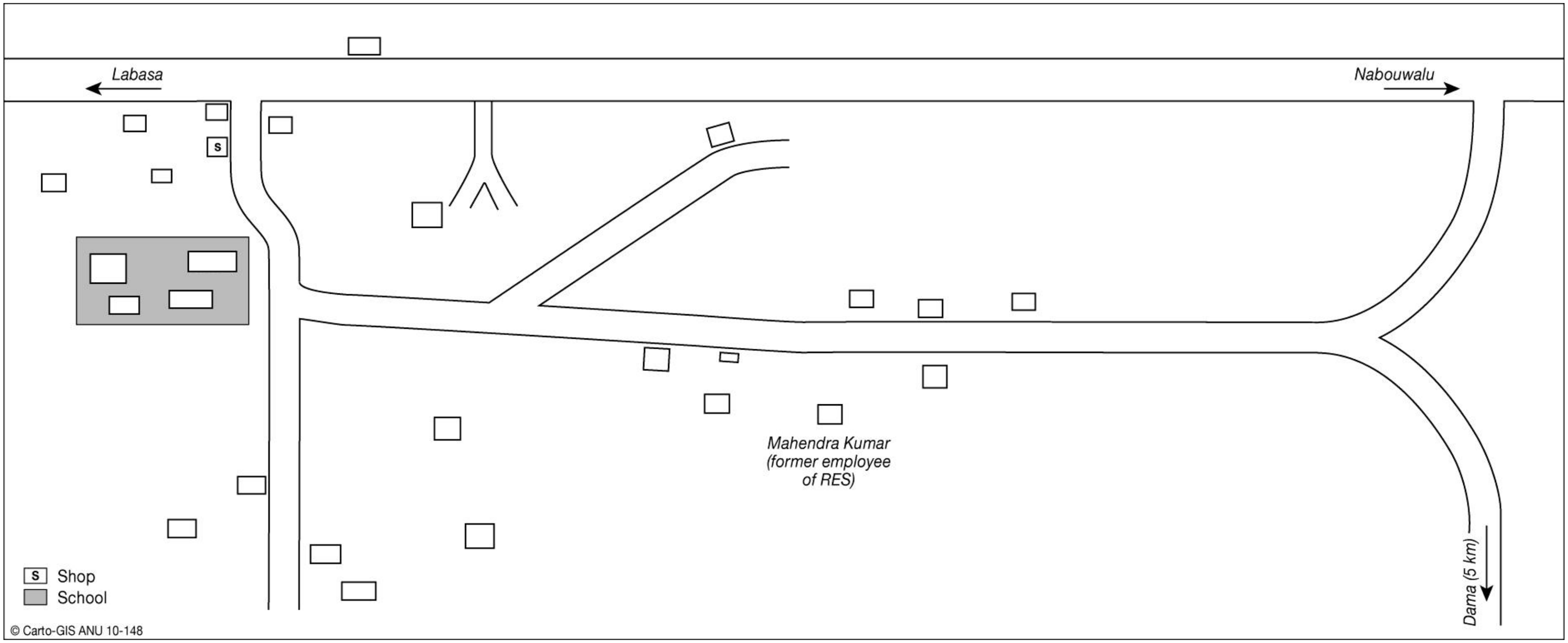
Map of Dama village



Map of Nakawakawa village



Map of Vunivao settlement



A5.3 Incomes in Bua Province

Information on household income in Bua province is taken from two sources. One is a survey conducted in 2005 as part of an ADB-funded Government study on the expansion of Nabouwalu Road (Government of Fiji 2005). This area is near to three of the four surveyed communities (Wairiki, Dama and Vunivao). The survey lists income in bands, and distinguishes between Fijian and Indo-Fijian households. Results were provided in table 5.4.1c.

Farm income was the main source of income among both indigenous and Indo-Fijians. The survey found that 50 per cent of indigenous Fijian households and 81 per cent of Indo-Fijian households received income only through farming (Government of Fiji 2005). Only 1 per cent of indigenous Fijian and 12 per cent of Indo-Fijian households received other regular income. Approximately 49 per cent of indigenous Fijian households had no source of regular income, whereas only 7 per cent of Indo-Fijian households were in this category. These figures are shown in table A5.3a.

Table A5.3a. Source of Household Income: Government of Fiji Survey Sample in Bua Province (per cent of surveyed households)

	Indigenous Fijian Households	Indo-Fijian Households
No regular cash income	49	7
Farm income only	50	81
Farm income plus other	1	12

Source: Government of Fiji Survey (2005)

The 2007 survey conducted by Urmee (2009) as part of her research on the *RESCO Program* generally confirmed the findings of the ADB-funded Government survey. Urmee also found that most income flows were irregular. Only 32 per cent of households surveyed by Urmee received the same income every month, with 37 per cent receiving less than average income for several months each year, and 31 per cent receiving most of their income over a few months and no income in other months.

The 2005 *Rural Electrification Survey* conducted by the Department of Energy provides specific information on the source of household income for three communities surveyed for this research: Wairiki, Dama and Nakawakawa. Households in each community were asked about their main sources of income, and identified the most, second most, and third most important source of income. The findings are presented in table A5.3b.

Table A5.3b. Main sources of Income in Surveyed Communities: 2005 *Rural Electrification Survey* (number of observations)

	Wairiki			Dama			Vunivao		
	Most	Second	Third	Most	Second	Third	Most	Second	Third
Making Handicrafts	0			4	1		0	0	0
Agriculture or Fishing	13	3	1	15	3		20	2	0
Working for Other People	3			3	10		7	20	0
Money from Relatives	2	2			1	10	0	0	20
Other	0						38*	1	

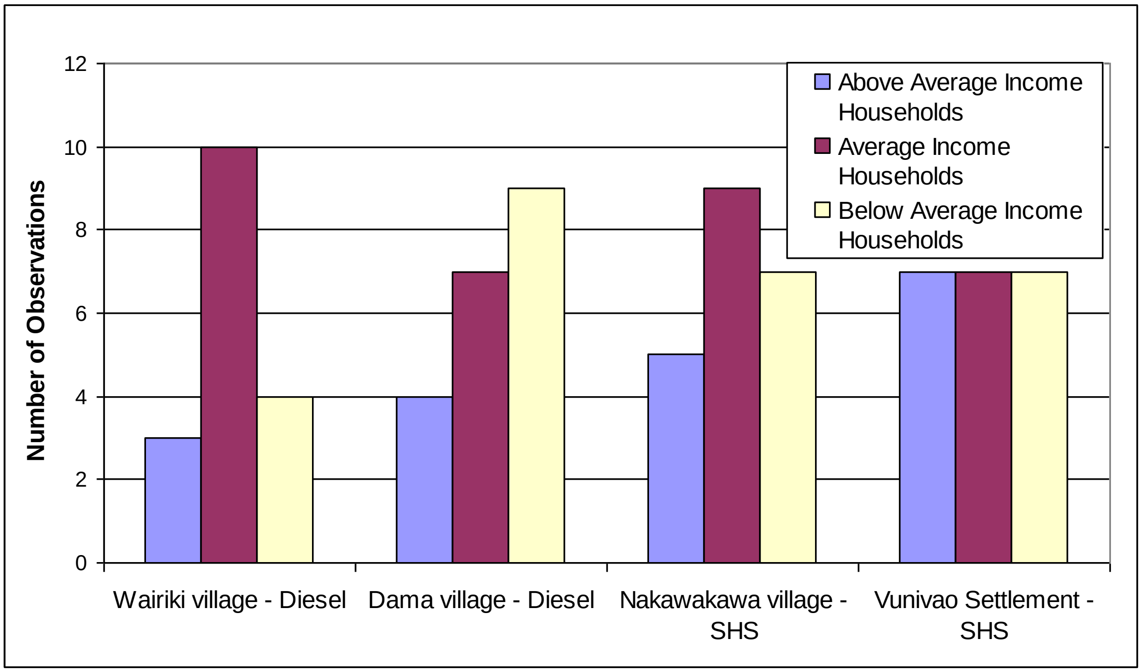
*34 of these responses involve rice farming.

Findings were again largely consistent with those of the ADB-funded Government survey. Indigenous Fijian villages were involved mainly in agriculture, with some households also working for other people or receiving money from relatives in urban centres. Indo-Fijian settlements were involved in a wider range of activities. Notably, five surveyed households in Vunivao were involved in running businesses, which included either shops or taxi/carrier vans. These households tended to have relatively high incomes.

A5.4 Indicators of Income and Wealth among Surveyed Households

Houses surveyed as part of this research were placed in categories based on the state of the house (such as its size relative to the number of occupants, whether the walls had holes or gaps, if there were windows, the use of a wooden or dirt floor), and its content (ownership of any electrical appliances, furniture). Figure A5.4a. shows the state of households in surveyed areas. Houses in Dama and Nakawakawa villages appeared to be the least wealthy, with nine households in Dama and seven households in Nakawakawa listed as appearing as below average income. The majority of households in Wairiki appeared to be of average income. In Vunivao, an equal number of households were included in each category.

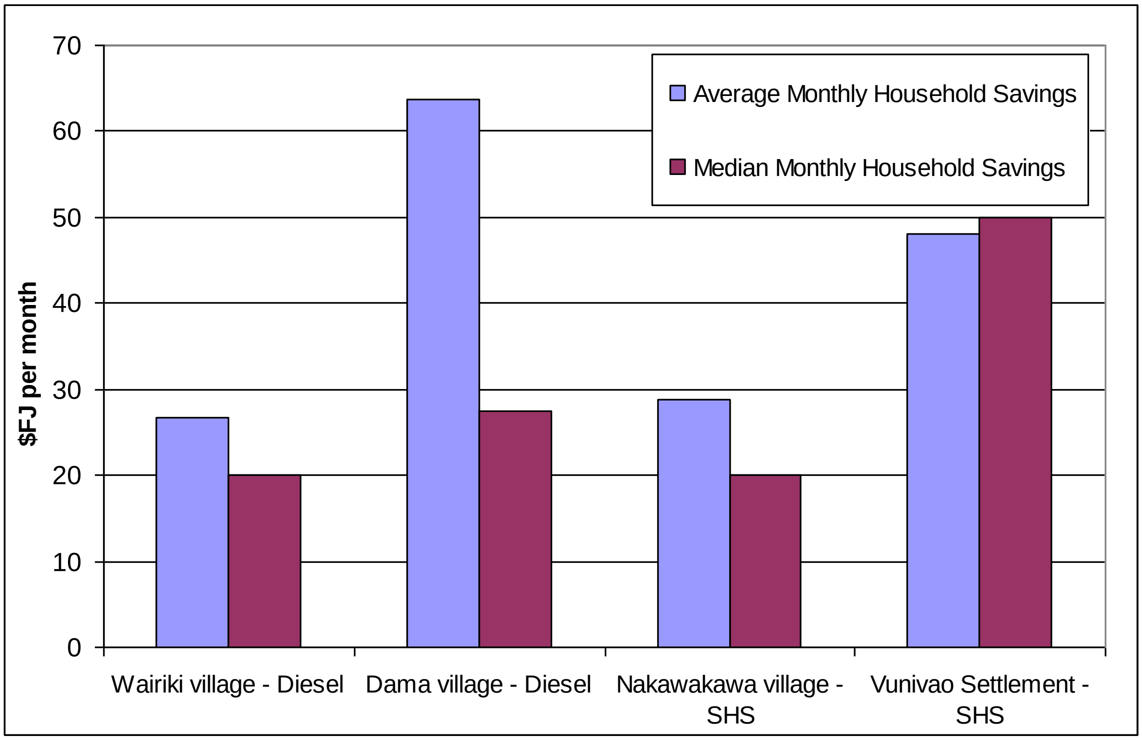
Figure A5.4a. State of Surveyed Households



Households were also asked about monthly savings, as a proxy for a question on income (which was excluded, as outlined previously). Monthly household savings data are shown in figure A5.4b. The figure shows average and median savings of households, as in three of the four communities several outlier responses distort the averages and suggest higher savings that were actually common in those communities.[202] Median monthly savings in the Indo-Fijian community of Vunivao are higher than those in the other communities. This is consistent with what is known about cash incomes and livelihoods in the four communities. Savings in the three indigenous Fijian communities are also fairly similar, with median monthly savings in Dama being FJ$5 higher than in the other two indigenous communities, possibly because of the higher number of households that work for others as a secondary source of income (as highlighted in the 2005 *Rural Electrification Survey* and detailed in Appendix A5.3).

[202] In the most extreme case, one elderly person surveyed in Dama claimed savings of FJ$500 per month, which she received from remittances sent by a daughter who lives in the United States. The removal of this response would reduce the average savings in Dama to FJ$40 per month, below those of Vunivao.

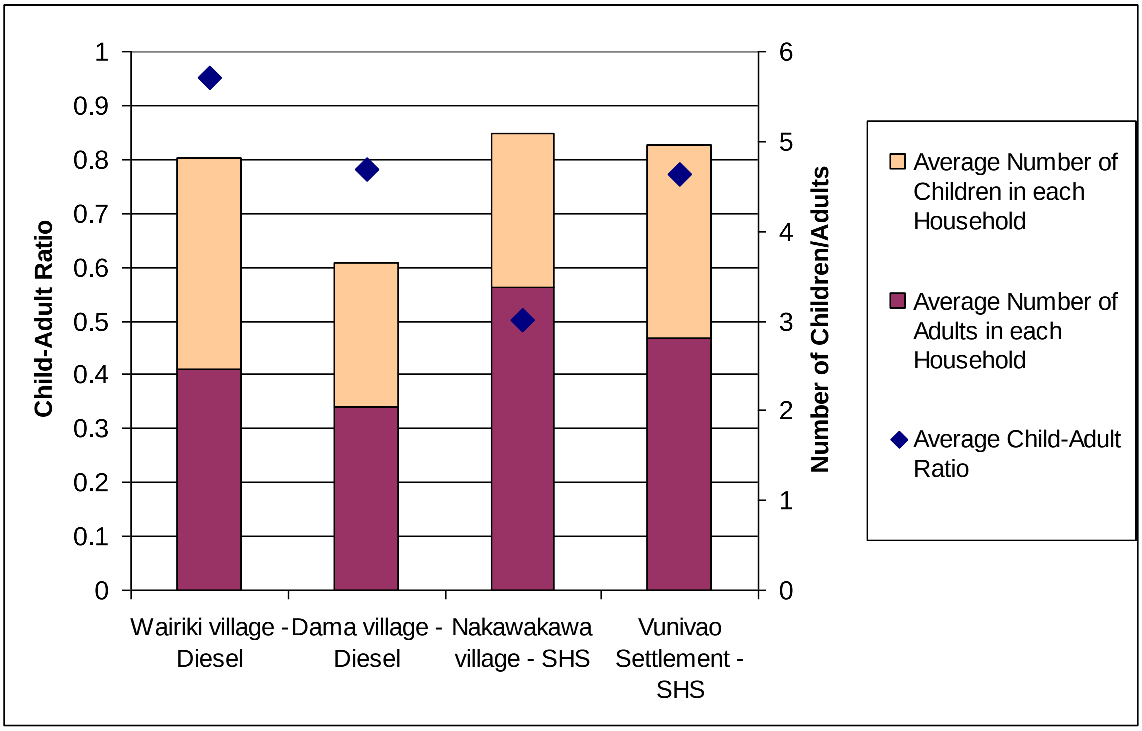
Figure A5.4b. Household Savings in Surveyed Areas



A5.5 Size and Child-Adult Ratio of Surveyed Households

Survey data on the size and child-adult ratio of surveyed households in each community are shown in figure A5.5a.

Figure A5.5a. Profile of Surveyed Areas (average number of adults and children in each household)



A5.6 Survey Questionnaires

Rural Electrification Survey – Main Survey
(completed by all surveyed households)

General

1. Name: ____________________ 2. Age: ___________

3. Gender: _____________ (male/female)

4. How many people normally live in your house?

Adults		Children	

5. What part of your household cash income each month is:

Saved ……………………………………………………$__________
Spent on energy*………………………………………....$__________
*(including all petrol, kerosene, diesel, wood, electricity etc purchased)

6. Please write down your household's expenditure on cooking fuels in the table below:

Cooking fuels used (can be more than one):	Yes/No	Amount	Expenditure ($/month)
Kerosene		Ltrs/month	
LPG (gas)		Ltrs/month	
Electricity		Not applicable	
Wood		Kg/day	

7. Please write down your household's expenditure on lighting fuels in the table below:

Lighting fuels (can be more than one):	Yes/No	Amount	Expenditure ($/month)
Kerosene		Ltrs/month	
Benzine		Ltrs/month	
Electricity		Not applicable	
Candles		Not applicable	

8. Please write down your household's total expenditure on the following items:

<table>
<tr><th>Fuel</th><th colspan="2">Amount used by the household:</th><th>Main purpose(s)?</th><th>Cost ($/month)</th><th>Cost in 2008 when prices were high ($/month)</th></tr>
<tr><td>LPG</td><td colspan="2">(Ltrs/month)</td><td></td><td></td><td></td></tr>
<tr><td>Kerosene</td><td colspan="2">(Ltrs/month)</td><td></td><td></td><td></td></tr>
<tr><td>Petrol</td><td colspan="2">(Ltrs/month)</td><td></td><td></td><td></td></tr>
<tr><td>Diesel</td><td colspan="2">(Ltrs/month)</td><td></td><td></td><td></td></tr>
<tr><td>Wood/biomass</td><td colspan="2">(Kg/<u>day</u>)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Car batteries</td><td>Number used/month</td><td>Charges per month</td><td rowspan="2"></td><td>Cost of charging</td><td rowspan="2">Not applicable</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Disposable batteries</td><td>Type of battery</td><td>Number used/month</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">Not applicable</td></tr>
<tr><td></td><td></td></tr>
</table>

Use of electricity

9. Is electricity needed for any business or money making activity in the village/settlement? _______ (Yes/No)

If yes, what activity? _______________________

10. Does anyone in your household make money in a way that requires electricity? _______(Yes/No)

11. How many lights are in your house? (including exterior lights) _________

12. Please list the appliances that use electricity in the house:

Appliance (eg, radio)	Number of appliances	Hours used per day (approx)	Importance (1 = most important, 2 = second most important, etc)

13. What are the thee most important appliances for you (including appliances you now own, and appliance you do not own but would like to purchase if you had more power available):

1.	(most important)
2.	(2^{nd} most important)
3.	(3^{rd} most important)

Cost of electricity

14. Do you think electricity is cheaper or more expensive than kerosene and batteries for lighting? (please tick)

Electricity is cheaper than kerosene and batteries	
Electricity is about the same as kerosene and batteries	
Electricity is more expensive than kerosene and batteries	

15. How much does your household pay for electricity each month? __________($/month)

16. Is this different to how much you paid in 2008 when fuel prices were high? __________ (Yes/No)

If yes, how much did you pay then ____________($/month)

17. What are charges for electricity based on? (please tick)

Same for all households		Metered or prepayment	
Number of appliances per house		No specific charge, money is raised when needed	

18. If there is no specific charge, and money is raised when needed, please explain how money is raised:

____

19. Who collects the money?

____

20. How is money collected? (please tick)

Weekly		Monthly	
Fortnightly			

21. Why did the village/settlement adopt this system? (please tick)

Decided by head of village		Other (please explain): ____	
Recommended by Department of Energy			

22. What happens to households who do not pay?

Disconnection straight away	
Disconnection after ____ days	
Nothing	

23. Has anyone been disconnected for non-payment?

_________________ (Yes/No)

24. Is the way the money collected: good/not good? _____________ Why?
____

25. Is the money: too little, just right, or too much? ________________ Explain:
____

Access to electricity

26. How many households in the village/settlement do not have electricity? __________

27. What is the main reason they don't have electricity? (please tick)

No materials available to connect more houses		Don't want electricity	
Too expensive		Other (please explain): _______________________	
Unreliable power			

Supply of electricity

28. How many hours is electricity available each day?

_______________________hrs

29. Quality of power: (please tick)

Quality is good	
Lights get dim or flicker in evenings	
Not enough power for present needs	

Security of electricity supply

30. How often does the power go off when it is supposed to be on? (please tick)

Several times a week	
Maybe once a week	
About once a fortnight	
Probably once a month	
Less than once a month	

31. How long does it usually stay off?

Short time (less than 10min)	
Maybe half an hour	
An hour or two	
A day or two	
A week or more	

32. What is the longest time the power has been off (in days)? ___________

Reason: ____

Preferences

33. Why did your household choose to install a diesel generator OR solar PV (SHS) for its electricity? (please tick as many boxes as you want)

Decided by head of village/settlement		It is more reliable	
It was recommended by the Department of Energy		It is better for the environment	
It was cheaper		Its cost is always the same	
It gives us more power		I can use power whenever I want	
It does not depend on good weather to work		It does not need fuel, which runs out	
Because each house has one, I can use power at my neighbours house when my electricity is not working		Other (please explain):	
I do not pay for the power of other households			

34. How important is the reliability of electricity supply? (please tick)

Very important	
Important	
Not so important	

35. Would you pay more for a reliable electricity supply? (which is never off when it is supposed to be on) __________ (Yes/No)

How much more? ____________ ($/month)

36. Do you have any other comments about electricity in your village?

____

37. How did the high prices in 2008 affect your household?

____

____

____

38. As a result, how much extra did your household spend per month on:

food: ___________________

energy*: __________________

*(including electricity, kerosene, LPG, petrol, diesel etc)

39. What had a greater effect, higher energy prices, or higher food prices (please tick)?

Higher energy prices	
Higher food prices	

Diesel Generator Survey

TO BE COMPLETED BY SUPERVISOR/OPERATOR OR COMMITTEE MEMBER

Operation

1. Diesel generator operating hours (per day) (start-stop)

Diesel operating hours (per day)	Start (time)	Stop (time)
__________________________Hours per day		

2. Who makes the decision about when electricity should be available? ________________

3. Can longer hrs be arranged? __________ (Yes/No) 4. How? _________________________

5. Who pays for extension of hours? ______________________

Fuel

6. Quantity of fuel used in a typical month? ________________

7. Describe records that are kept of fuel used per month: ___________________

8. Where is fuel purchased? (and from how far away?) ______________________

9. How is fuel received or stored after being bought? (eg 200L barrels) ____________________

10. Usually, how often is a fuel purchase made? (days between fuel purchases) ________________

11. What is now being paid for fuel per litre? ______ 12. What was paid for fuel at its highest price in 2008?______

Reliability and Maintenance

12. Number of breakdowns per year _______________ 13. Average cost to repair _________________

14. About how much per year does the village pay for maintenance and repair? (not including fuel) ____________

15. Who is responsible for maintenance of equipment? (please tick box)

Village technician		Company or paid individual from outside	

16. How are they compensated for their time? ____

If they are paid, where does the money come from? ___________________________________

17. What types of problems have commonly caused breakdowns?

Problem		Yes/No	Total days in 2009	Total days in 2008 (when fuel was expensive)
Technical problem	Fixed immediately			
	Not fixed immediately because there was no money to pay for repair			
	Not fixed immediately because outside technician or equipment was needed			
Ran out of fuel	None was available where it was bought			
	Not enough money			
	Someone forgot to get more fuel			
	Thought there was enough but ran out			

18. Did the high price of fuel in 2008 impact on electricity generation? ____(Yes/No)
If yes, how?

____

Solar Home Systems (SHS)

(Completed by all households with a SHS)

Electricity

1. Is sufficient electricity provided by the SHS? _______ (Yes/No)

2. If you could get more power for appliances, how much extra would you be willing to pay for electricity? ___________________________________ ($/month)

Maintenance

3. How often does someone come to check your solar PV (SHS) system?

Only when I ask someone to come		Every two months	
Weekly		Less frequently than every two months. How often? ____________________________	
Every fortnight			
Monthly			

4. Who is responsible for maintenance of equipment? (please tick box)

Village technician		Company or paid individual from outside. Who? _________________	

5. How are they compensated for their time? ____

If they are paid, where does the pay come from? __________________________________

6. Where does money for repairs come from? _________________________

7. Is there a committee that looks after the maintenance of electricity in the village/settlement? _______________ (Yes/No)

8. Do you think the committee does a good job? Why?

____

Yes	
No	

9. Are you involved in the committee at all? How? ______________________________

10. Is the maintenance provided: (please tick box)

Very satisfactory		Not satisfactory Why? ___________________________________	
Satisfactory			

Reliability

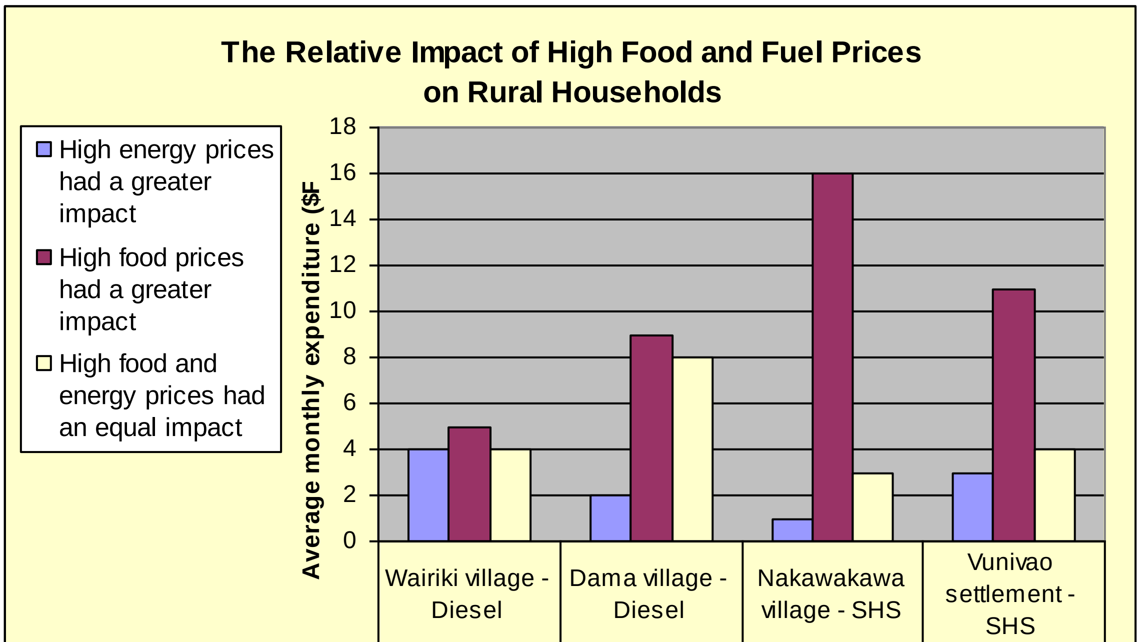
11. What types of problems have commonly caused power outages?

Problem		Y/N	Total days in 2009	Total days in 2008
Technical problem	Fixed quickly			
	Not fixed immediately because there was no money to pay for repair			
	Not fixed immediately because outside technician or equipment was needed			
Did not pay fee	Not enough money			
	Could not get to the shop/post office to pay			
	Someone forgot to pay fee			

A5.7 Impact of High Food and Fuel Prices

International prices for food staples peaked at approximately the same time as fuel in 2008 (Evans 2008; ODI 2008). In Fiji, this affected the price of many foods that rural households purchase, including rice and canned tuna and meat. The survey sought to find out what had the bigger impact on rural households: high food or high fuel prices. Households were asked directly which of these had the bigger impact. The results are shown in figure A5.7a.

Figure A5.7a. Rural Perceptions on the Comparative Impact of High Food and Fuel Prices



	Wairiki village - Diesel	Dama village - Diesel	Nakawakawa village - SHS	Vunivao settlement - SHS
High energy prices had a greater impact	4	2	1	3
High food prices had a greater impact	5	9	16	11
High food and energy prices had an equal impact	4	8	3	4

In all communities, high food prices were regarded as having a bigger impact on households than high fuel prices. Many households also said that both had a similar affect on their household. Generally, households said that whereas fuel prices had been volatile, food prices had simply increased, with current prices similar to those in 2008. Households in Vunivao were especially affected by high food prices, as many rely on cash incomes to purchase food. Those on state pensions (such as disability pensions) also said they had been very affected.

When asked why food or fuel had a bigger impact, typical responses included:

Food had a bigger impact:

- "We can go without kerosene, but not without food for the kids" (Interview in Dama, November 2009)
- "Both are so expensive. I normally don't buy food now (although I used to), because it is too expensive, instead I just grow it. Rice is very expensive." (Interview in Dama, November 2009)
- "The price of food is expensive and never decreases or fluctuates (like fuel does), it just goes up. For example, rice has increased from $9 (per 10kg) in 2007 to $21." (Interview in Wairiki, November 2009)
- "Food prices increase every month while fuel fluctuates" (Interview in Vunivao, December 2009)
- "It is too expensive now. We have to go without some food items when I go shopping. Fuel is not a problem but food has had a great affect on me and my family." (Interview in Nakawakawa, December 2009)

Energy had a bigger impact:

- "Energy and fuel prices are expensive but for food the prices are Ok because we grow our own food, but we buy some things like sugar, rice and flour." (Interview in Dama, November 2009)
- "We can go without food purchased from the store, because we can simply eat our own crops. But we have to buy fuel (kerosene), even if the price is very high." (Interview in Wairiki, November 2009)

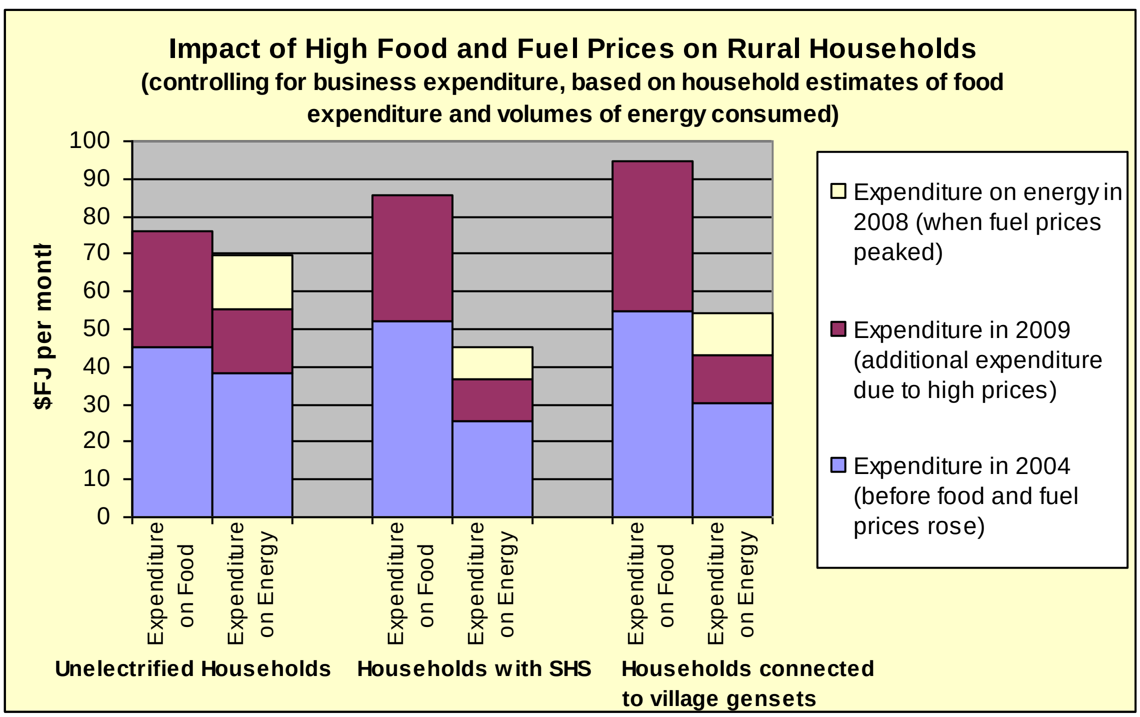
Both had an equal impact:

- "No problem as we are in the village. The prices do not affect us as much as those in the city." (Interview in Dama, November 2009)
- "Both are expensive." (Interview in Nakawakawa, December 2009)

- “(Both) is difficult to afford because we have no source of income” (Interview in Vunivao, December 2009)

Households were also asked about expenditure on food in 2004 (before prices rose) and in 2009 (at the time of the survey). The data are compared to household spending on fuel in the same period in figure A5.7b. The comparison shows that households spent more on food than on energy. It also shows that higher food prices had a greater impact in both absolute terms (the additional expenditure of households) and relative terms (the percentage increase in household expenditure in the two periods). Many households said that food prices remained at their 2008 levels at the time of the survey. If so, this could justify a comparison with 2008 household expenditure on energy (as fuel prices peaked in 2008). These figures are also included in figure A5.7b, and show that high food prices had a bigger impact than high fuel prices, even when including 2008 fuel prices. For un-electrified households, the difference in impact of the two was nevertheless minimal.

Figure A5.7b. Impact of High Food and Fuel Prices on Rural Households

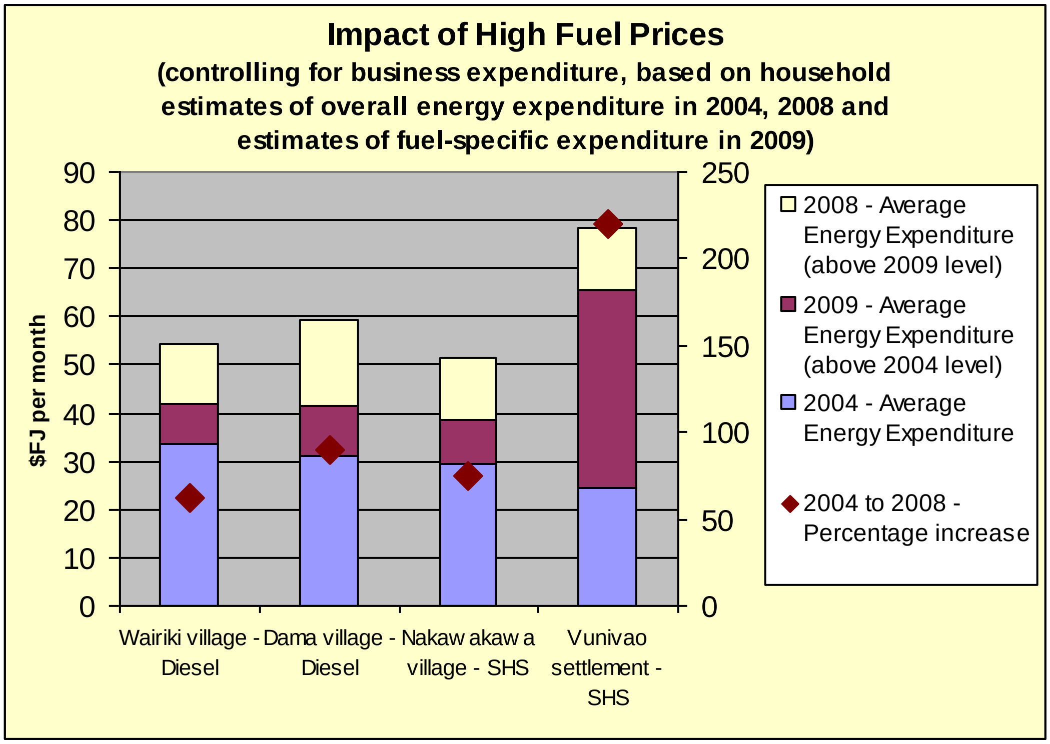


A5.8 Sensitivity Analysis: Results from Different Methods of Calculating Household Energy Expenditure

Household estimates of expenditure on energy in different years are provided in figure A5.8a as part of a sensitivity analysis. Unlike figure 5.5.1a, the data in figure A5.8a are not based on the volume of energy consumed but on household estimates of their expenditure on energy and fuels in different years (with 2009 expenditure based on the sum of household estimates of expenditure on individual forms of energy, and 2004 and 2008 data based on estimates of total household expenditure on energy). The figure shows that in the indigenous Fijian villages (and especially Dama and Nakawakawa), estimates of energy expenditure tend to be higher than expenditures calculated using the volumes of energy consumed. In the Indo-Fijian settlement of Vunivao on the other hand, estimates of expenditure are generally about FJ$10 per month lower than the data calculated using Prices and Income Board figures. In other words, whereas indigenous Fijian households seem to have overestimated their expenditure on energy, Indo-Fijian households seem to have done the opposite, underestimating their expenditure.

Figure A5.8a also shows the percentage increase in expenditure resulting from higher fuel prices, based on the household estimates of expenditure in the various years. The estimates of indigenous Fijian households result in increases that are similar to the calculations from Prices and Income Board figures (estimates are slightly lower in Wairiki). In Vunivao however the price increases are far higher, owing to the very low estimates of expenditure on fuel in 2004 (before fuel prices increased).

Figure A5.8a. Impact of High Fuel Prices in Surveyed Communities
(based on household estimates of energy expenditure)



The important point in comparing the two graphs is that the key findings shown in figure 5.5.1a remain true in figure A5.8a. The findings are the same whether data is based on: (i) calculations of household energy expenditure using Prices and Incomes Board figures, or (ii) household estimates of energy expenditure.

A5.9 Comparison of Survey Data with Existing Data

Data from the *Energy Use Survey* (2002-03) provide information on the proportion of households that consume different forms of energy. This data are compared to my survey findings in table A5.9a. The survey data from the *Energy Use Survey* mainly represent un-electrified households (households in 51 communities) and those connected to village diesel generators (households in 39 communities). Households with SHS are not surveyed. As a result, the *Energy Use Survey* shows a higher proportion of households using candles, kerosene or benzine (mainly for lighting) than does the survey carried out for this research. Interestingly, the use of batteries is far lower (the reason for this is not clear, although it may relate to the increased use of battery operated torches and radios in rural areas of Fiji between 2003 and 2009). The use of LPG is similar in both surveys. Consumption of diesel, super and pre-mix fuel is recorded differently in the two surveys, preventing direct comparison. Nevertheless, overall it seems that more households surveyed in 2002-03 consumed these fuels than households surveyed in 2009. This may be the result of: (a) the higher proportion of un-electrified households surveyed in 2002-03 (that are more likely to operate portable generators), and/or (b) the lower income levels of households in Bua province (surveyed in the 2009 survey) compared to those of other rural parts of Fiji.

Table A5.9a. Comparison of Household Energy Use: Energy Use Survey 2002-03 (Namoumou 2003), and Present Survey

Energy Use Survey (2002-03)		This Survey (2009)	
Energy Source	Proportion of households (%)	Energy Source	Proportion of households (%)
Diesel and Super	51	Diesel	18
Pre-mix	32	Petrol (Super and Premix)	23
LPG	35	LPG	36
Kerosene	100	Kerosene	81
Benzine	58	Benzine	30
Candles	32	Candles	18
Batteries (disposable)	27	Batteries (disposable)	87
		Batteries (car batteries)	10
		Wood	100

The *Energy Use Survey* (2002-03) also collected data on household use of energy for cooking.[203] These figures are compared to the results of the present survey in table A5.9b. The table shows that more households surveyed in 2009 used wood as their only form of cooking fuel than households surveyed in 2002-03. Conversely, in 2009 a smaller percentage used kerosene and (especially) LPG for cooking, although a slightly larger proportion used all three fuel sources. All households surveyed in 2009 used some wood for cooking, while the 2002-03 showed 2 per cent of households used only LGP.

These results represent different survey samples, with it being likely the households surveyed in Bua province in 2009 have lower cash incomes than the group surveyed in 2003-03. This would explain the higher use of wood and lower use of LPG among households in 2009. The higher use of only fuel wood for cooking may also reflect the higher price of cooking fuels in 2009 compared to 2002-03.

[203] Data on household use of energy for lighting were also collected, but only presented the 'primary' form of lighting used by each household. This information is of limited use as almost all households use various forms of energy for lighting.

Table A5.9b. Comparison of Household Energy Use for Cooking: Energy Use Survey 2002-03, and Present Survey

Energy Use Survey (2002-03)		Present Survey (2009)	
Energy Source	Proportion of households (%)	Energy Source	Proportion of households (%)
Wood	35	Wood	47
Wood and kerosene	22	Wood and kerosene	17
Wood and LPG	34	Wood and LPG	27
Wood and LPG and kerosene	7	Wood and LPG and kerosene	9
LPG	2	LPG	0

A5.10 Household Lighting

The average number of lights in households surveyed for this research project is shown in table A5.10a.

The same households were also asked about the number of lights in their house as part of the 2005 *Rural Electrification Survey* (excluding Nakawakawa, which was not included in the 2005 survey). The answers were similar, with slight increases in the number of lights recorded in every community, as seen in table A5.10a. This was commonly the result of rural households installing extra lights, which is against Department of Energy rules that allow only trained technicians to install wiring for safety reasons. In Vunivao, many households with average and above average incomes had two sets of lighting systems installed.

Table A5.10a. Average Number of Lights in Surveyed Households, 2009 and 2005

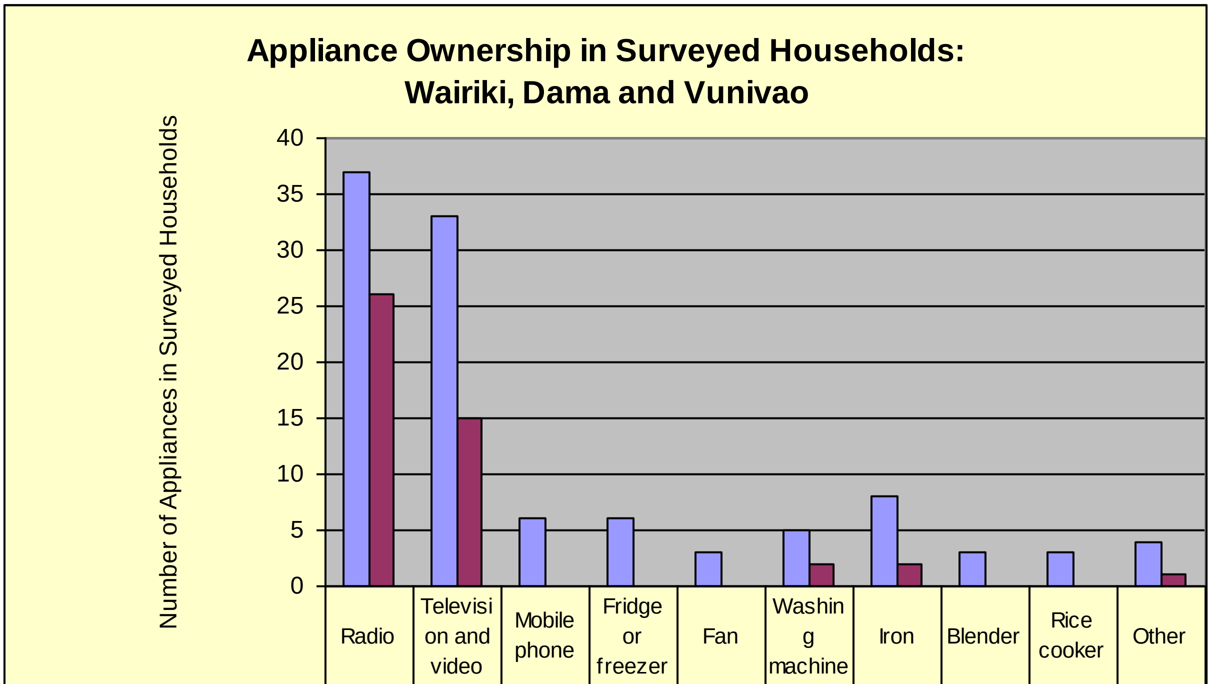
	Wairiki	Dama	Vunivao	Nakawakawa
2009	2.6	2.9	6.1	5.5
2005	2.4	2.5	4.2	n/a

A5.11 Household Electrical Appliances

Ownership of Appliances

Household ownership of appliances at the time of the survey is compared to answers given by the same survey sample in the 2005 *Rural Electrification Survey* in figure A5.11a. The figure excludes data from Nakawakawa, which was not surveyed in 2005. It shows a very large increase in appliance ownership among surveyed households. Ownership of television and video sets has more than doubled. In many cases, appliances not present in the surveyed communities in 2005 are now owned by households, such as fridges and freezers, fans, blenders and rice cookers. In the case of mobile phones, this rapid growth can be explained by the installation of mobile phone towers providing reception to much of Bua province.

Figure A5.11b. Appliance Ownership in Surveyed Households, 2009 and 2005



	Radio	Television and video	Mobile phone	Fridge or freezer	Fan	Washing machine	Iron	Blender	Rice cooker	Other
2009 - Number of Appliances	37	33	6	6	3	5	8	3	3	4
2005 - Number of Appliances	26	15	0	0	0	2	2	0	0	1

Prioritisation of Appliances

The survey also asked households what they considered to be the three most important electrical appliances. Households were told they could select both appliances they currently owned and appliances they would like to purchase. The responses, shown in table A5.11a, give some indication about household preferences in respect to electricity consumption, and are also a gauge to potential future demand for electricity in these areas.

Table A5.11a. Three Most Important Appliances as Selected by Households

	Wairiki	Dama	Nakawakawa	Vunivao	Total
Radio	7	5	9	3	24
Television and video/DVD	9	6	9	7	31
Mobile phone	2	1	0	0	3
Fridge or freezer	5	11	5	15	36
Fan	0	2	0	1	3
Washing machine	9	13	13	2	37
Iron	4	0	5	6	10
Blender	0	0	0	0	0
Rice cooker	0	0	0	8	8
Other	0	0	2	3	5

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