GHG Reduction through the use of Energy Efficiency & Renewable Energy

Photo: © Nick Wardrop

SPC Suva ENERGY EFFICIENCY and RENEWABLE ENERGY PROJECT (Lotus, Nabua, SOPAC)

SUVA, FIJI ISLANDS

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SPC Suva ENERGY EFFICIENCY and RENEWABLE ENERGY PROJECT was prepared in 2013 for SPC by Nick Wardrop of Sunergy Consulting, with input from Frank Vukikomoala and Robert Curuqara and other SPC staff. These included Aude Chenet and Brian Dawson.

Cover photograph; from kayak in Majuro Lagoon, Republic of the Marshall Islands, during King Tide event March 2011. Many low lying areas of Majuro Atoll are increasingly being inundated due to rising sea levels (Climate Change/ Global Warming). The two boys are standing on the top of their sea wall.

May 2013

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ACRONYMS AND ABBREVIATIONS

CFL	Compact Fluorescent Lamp
COP	Coefficient of Performance (Cooling kW/ Electrical Power kW)
DSM	Demand-Side Management
EC	Energy conservation
EDD	Economic Development Division
EE	Energy efficiency
EER	Energy Efficiency Ratio (sometimes called COP)
FEA	Fiji Electricity Authority
FTL	Fluorescent Tube Lamp
GHG	Greenhouse Gas
ICT	Internet and Communication Technologies
IRR	Internal Rate of Return
LED	Light Emitting Diode
LRD	Land Resources Division
PHD	Public Health Division
PICTs	Pacific Island Countries and Territories
PV	Photovoltaic (solar electric)
RE	Renewable Energy
SOPAC	Applied Geoscience and Technology Division
SPC	Secretariat of the Pacific Community
TOR	Terms of Reference
TVET	Technical and Vocational Education and Training
UPS	Uninterruptable Power Supply
VAT	Value Added Tax (15% in 2012)

EXECUTIVE SUMMARY

Background

SPC is in the process of developing a greenhouse gas emissions reduction strategy and a green office policy. SPC has already prepared a greenhouse gas emissions inventory for the organisation that covers its offices across the region. The next stage of the process was to identify cost effective measures to reduce the organization's greenhouse gas emissions. This will also enable SPC to set an achievable emissions reduction target. The emission reduction strategy will be supported with the development of an organization environmental policy and staff training and awareness activities.

SPC has already commenced the process of identifying emission reduction measures at Noumea office facilities but seeks to extend this to selected office buildings in Suva, Fiji. As a result of this objective the services of Sunergy Consulting were contracted to assist with conducting and analysing energy audits for its offices in Nabua, SOPAC and Lotus office buildings in Suva, Fiji. Some energy efficiency measures are already being introduced at the Lotus building office facilities. The intended output of this work is the identification of a package of cost effective technologies and office operational procedures that would reduce energy use at each of the three office buildings mentioned above.

Also of concern are the increase in electrical energy prices, and the increase in energy consumed per capita with increased use of electrical appliances and equipment, and consequent increase in GHG emissions.

Scope of the Study

The consultant was to complete a review of SPC's Fiji offices energy usage and current operational practices that influence energy usage and compile a report identifying energy efficiency/renewable energy options that SPC could introduce to reduce its greenhouse gas emissions. The consultant was to assess energy efficiency options for air conditioning and lighting systems, information technology/office equipment, building envelope energy efficiency (windows, openings, natural lighting), and other relevant energy consuming appliances.

The report includes:

a. current base energy consumption profiles (both energy and cost, and splits across services);

b. recommended energy efficiency and other measures showing expected reductions in energy consumption, (including the use of renewable energy technologies), and showing the potential contribution of each measure to emission reductions (using the Fiji Electricity Authority emission factor and standard emission factors for other energy use);

c. financial analysis of a package of measures, including estimated investment costs, Internal Rates of Return, and payback periods;

d. recommendations regarding improvements in the quality and reliability of energy related services, and the estimated cost of doing so.

Methodology

To facilitate the audit process SPC provided the support services of a dedicated junior officer/ intern for the duration of the audit and additional support and guidance of senior officers of the Energy Programme of the Economic Development Division. The consultant was able to have initial planning discussions with the staff of the SPC Energy Programme at the commencement of the audit process in December 2012, but was unfortunately constrained by Cyclone Evan and Christmas. However the junior officer was able to support the audit process by collecting basic energy and cost data, conducting the energy audits, setting out the detailed audit analysis, accessing quotes for recommended energy efficiency/renewable energy equipment and other duties as requested by the SPC Energy Adviser. The undertaking by Robert Curuqarawith Frank Vukikomoala was substantial, and with collaboration, formed the basis of this study.

Major Findings

Unsurprisingly, the major use of electricity across all 3 sites was for Air Conditioning (59.9%). However, the Nabua campus was the worst offender (71%), followed by Lotus and lastly SOPAC. At first view, it was not expected that the second largest user of electricity would be Servers (14.4%) which are situated at the Lotus Building (19%) and SOPAC (23%). There are none at Nabua. The third largest is office equipment (10.9% - Computers 6.7%; UPS 1.1% and Printers and Copiers 3.0%). Fourth largest is lighting (8.7%) and lastly others (6.1% fridges, freezer, water coolers, kitchen equipment, small miscellaneous).

Note that monthly energy use (kWh) has been used to allow easy comparison with FEA's billing period.

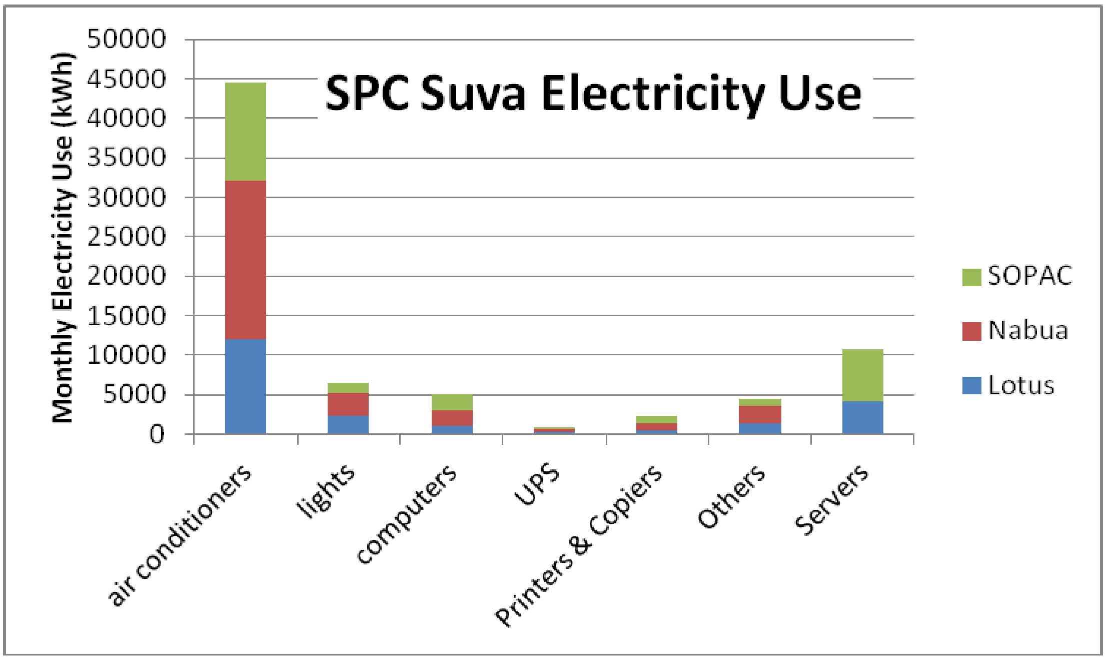

Figure 0.1: SPC Suva Overall Electricity Consumption by Service and Site

Looking at the tabulated results (Table 0.1) it is noteworthy that the heaviest energy user per capita was Nabua, followed by SOPAC and Lotus, which is surprising as Nabua does not have the servers, an appreciable load at both Lotus and SOPAC. On the other hand, SOPAC has the highest energy use by unit of floor area, whereas Lotus and Nabua are almost the same. It is possible that Nabua and SOPAC have the worst building envelopes energetically, with little insulation and high infiltration loss, and high surface area to volume ratio's, making heat ingress easier.

Table 0.1: SPC Suva Audit Results (kWh/month)

	Lotus	Nabua	SOPAC	TOTAL	Percentage	
air conditioners	11961	20095	12423	**44479**	59.9%	
lights	2371	2767	1334	**6472**	8.7%	
computers	1040	2015	1951	**5006**	6.7%	8055
UPS	228	395	188	**811**	1.1%	10.9%
Printers & Copiers	424	886	928	**2238**	3.0%	
Others	1427	2078	1003	**4508**	6.1%	
Servers	4059	0	6641	**10700**	14.4%	
TOTAL	**21510**	**28236**	**24468**	**74214**	100.0%	
Employees	120	78	107	305		
Energy Use/person	179	362	229	243		
Floor Area (m^2)	2137	2722	961	5820		
Energy Use/m^2	10.07	10.37	25.46	12.75		

The highlighted areas sum office equipment monthly energy use (orange) and the corresponding percentage contribution to energy use (yellow).

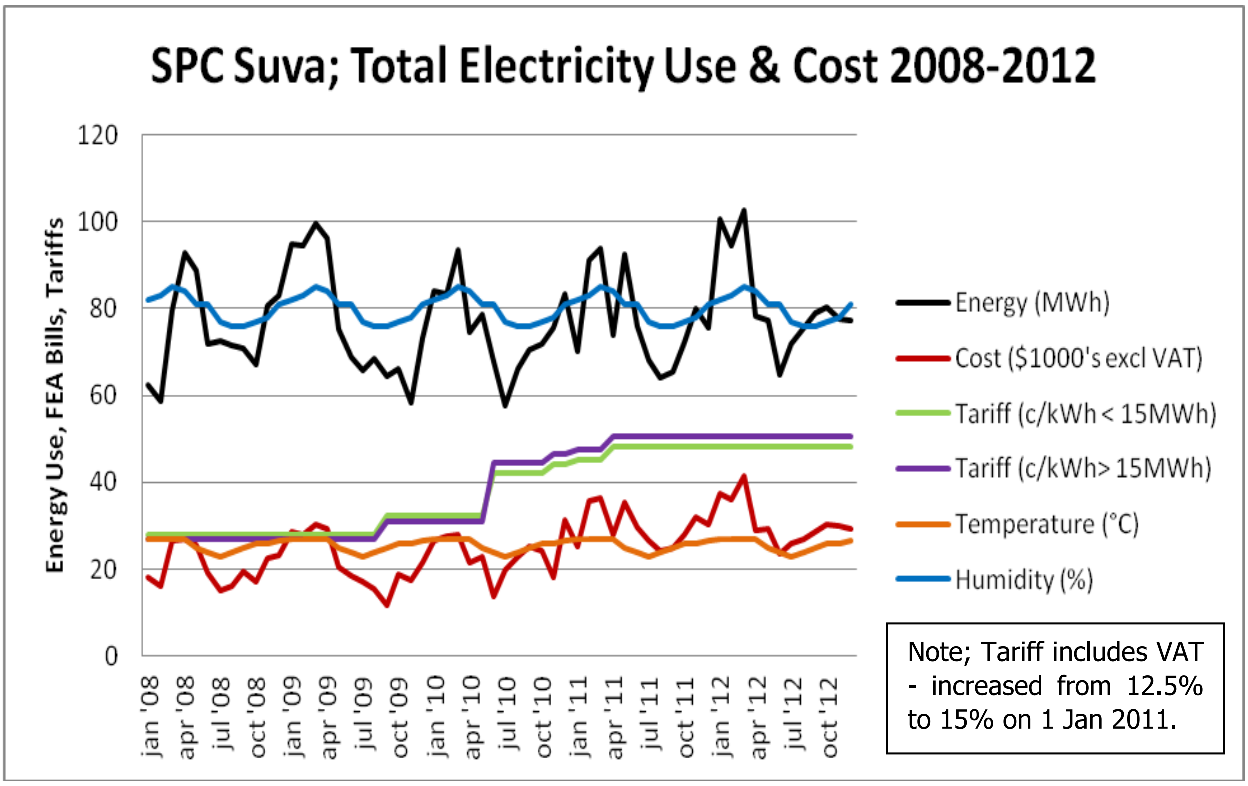

Figure 0.2: SPC Suva Overall Electrical Energy Usage & Cost (2008 – 2012)

Absolute Energy Use over the 5 years (2008 -2012) has not risen much (about 9%) to an average of 80MWh per month, whereas costs have risen 50% in the same period to F$35,000 per month, largely due to tariff increases.

It is noteworthy that peaks in consumption occur between January to March each year, and the minimums occur between July to September each year, in line with seasonal temperature and humidity variations. This is not surprising for facilities where the major electrical load is air conditioning, with the human desire to keep cool.

Financial Analysis – All 3 sites

While each site was audited separately, and findings for each were also presented separately, it was felt that an overall approach was needed to analysing the financial implications of reducing SPC Suva's energy use, as bulk purchasing and implementation could reduce costs.

To this end, financial analysis has been undertaken for all 3 sites at once.

Table 0.2: Costs and Annual Savings of proposed Programmes

	Project	Cost to Implement ($1000s)	Annual Savings (MWh)	Cost Savings ($1000s)	Internal Rate of Return	Payback period (years)	CO_2e avoided (tonne)
1	Monitoring	$20	25	$12.5	62.5%	1.6	12.5
2	Conservation Program	$25	50	$25	100%	1.0	25.0
3	Building Envelope	$250	100	$50	19.4%	5.0	50.0
4	Air Conditioners	$480	120	$60	10.9%	8.0	60.0
5	Servers	$300	60	$30	7.8%	10.0	30.0
6	Office Equipment	$175	45	$22.5	11.4%	7.8	22.5
7	Lights	$100	50	$25	24.7%	4.0	25.0
8	PV System (225kWh)	$900	250	$125	12.6%	7.2	125.0
	TOTAL	**$2250**	**700**	**$350**	**14.5%**	**6.6**	**350.0**

Assuming an electricity cost at the upper range of F$0.50/kWh (VAT included), and an emission factor of 0.50 kg CO_2/kWh (or 0.5 tonne CO_2/MWh). See Section 2.2.4 for explanation.

Conclusions and Recommendations

The buildings at Nabua and SOPAC are older buildings not designed for air conditioning, and so these buildings require most attention for reduction of "leakiness" in terms of heat ingress. This should have a major impact in terms of reducing energy use. A combination of building improvements, and AC upgrade will lead the impact, together with Energy Conservation measures.

Surprisingly, the servers at SOPAC and Lotus are the second highest energy use. More detailed monitoring is required here to validate this and track measures to reduce electricity use.

Office equipment and lighting upgrades complete the actions required.

The detailed discussion is in Section 5.

1 INTRODUCTION

1.1 Overview

The Secretariat of the Pacific Community (SPC) is an international organisation which has its main regional office in Noumea, New Caledonia, and sub-regional offices in Fiji, distributed over 3 compounds in Suva (see aerial view below). SPC's work programme is determined by members, and all of its regional initiatives aim to support members' national policies and plans

SPC works in a wide range of sectors with the aim of achieving three development outcomes – sustainable economic development, sustainable natural resource management and development, and sustainable human and social development. Sectors covered include public health, geoscience, agriculture, forestry, water resources, disaster management, fisheries, education (community, technical and vocational education and training (TVET), quality and standards for all school levels), statistics, transport, energy, ICT, media, human rights, gender, youth and culture to help Pacific Island people achieve sustainable development. To achieve its aims, SPC Suva employs some 375 professional and support staff.

The Leaders of the 22 member Pacific Island Countries and Territories (PICTs) which comprise SPC (together with 4 of the founding countries), have over many years, expressed deep concern about the impacts of Climate Change and Global Warming on their respective countries. They are implementing both mitigation and adaption measures, although, being small in the global context, their greenhouse gas (GHG) emissions are also very small.

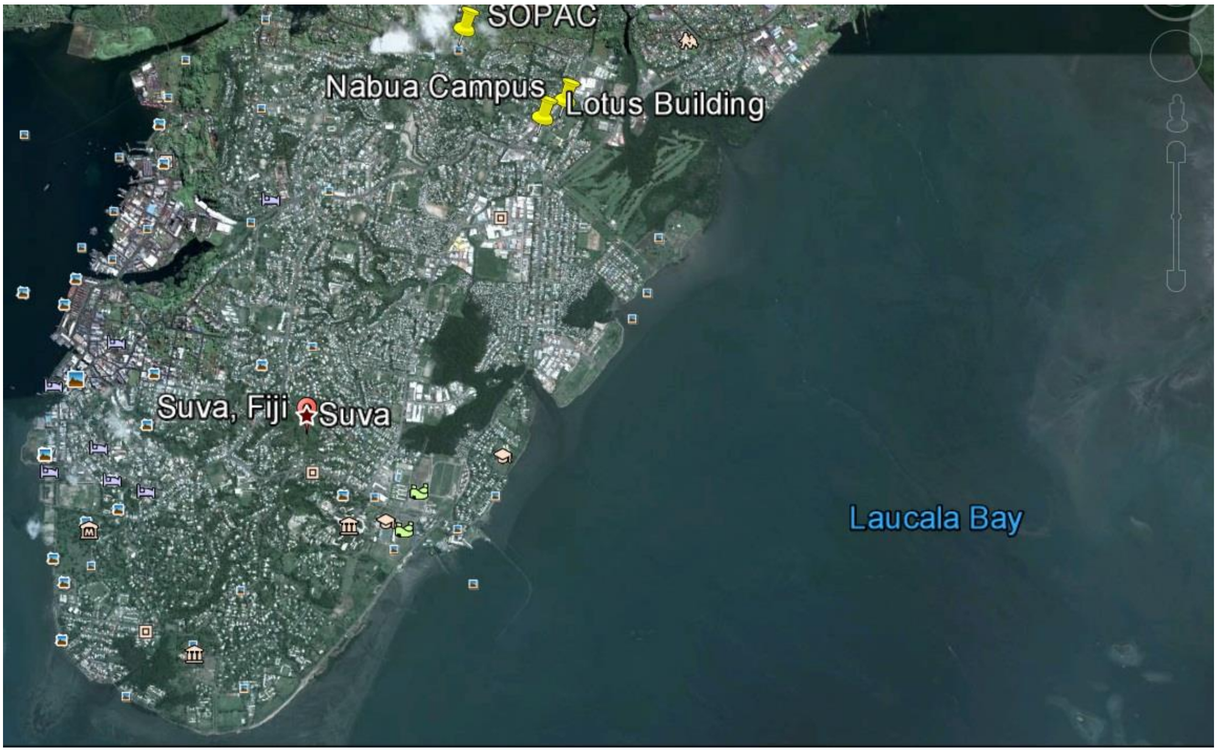

Figure 1.1: The Three Sites of SPC Suva under consideration

1.2 Objective

The main objective of this consultancy was to reduce costs and hence GHG emissions from the use of electricity in the Suva offices of SPC, by investigating the cost effectiveness of implementing programs such as;

- Building Envelope improvements,
- Energy Conservation (EC),
- Energy Efficiency (EE), and
- Renewable Energy (RE).

1.3 Approach and Methodology

The approach and methodology agreed with the Secretariat of the Pacific Community (SPC) due to the limited time the consultant had in Fiji, and the scale of the project, was as follows:

1. Assist the EDD officer in charge of the audit process, and the junior officer, with methodology, monitoring techniques, requisite equipment and analysis to evaluate the energy use and building envelopes of the 3 sites under investigation.

2. Checks of audit data against billing, requests for additional information, and preparation of the draft report outlining results and making recommendations for future action.

3. Discussion of the draft report with SPC, incorporation of comments and suggests, and production of the final report.

The above approach and methodology also conform to the Scope of Work outlined in TOR for the project.

Being the largest energy use within SPC (close to 2/3), investigations centred on office cooling, and first and foremost the efficiency of the building envelopes.

Following this, the cost of upgrading Air Conditioners was also investigated, which were mainly smaller air conditioners (split system, up to 7.5 kW cooling capacity). There were a few larger split system ceiling air conditioners (7.5 to about 30 kW cooling capacity), used in the Lotus Building.

The lesser energy users were also investigated and comprised.

- Servers
- Office electronic equipment including computers, printers/ copiers and UPS;
- Lighting.
- Other (was not considered in detail as was <10%).

2 FIJI INFORMATION

2.1 Overview

Electrical Energy for the SPC Offices, which are based in Suva, Fiji, is supplied by the Fiji Electricity Authority (FEA), and is generated from two main sources of energy within Viti Levu, but there is a growing amount from newer RE sources. Fiji consists of 2 major islands, Viti Levu and Vanua Levu, which cover about 87% of the country's total land area. There are many other islands, some large, some very small. The island of Viti Levu has the majority of population (about 70%), and so unsurprisingly the largest proportion of the nation's energy use is consumed here.

2.2 Fiji Electrical Energy

The Fiji National Energy Policy (approved in 2006) vision is for a sustainable energy sector, while its mission is to provide an enabling environment to achieve this vision. The National Energy Policy has 4 strategic areas, being:

- Energy Planning
- Energy Security
- Power Sector
- Renewable Energy

2.2.1 Fiji Electricity Authority

The Fiji Electricity Authority (FEA) was established as a statutory body in 1966, and was tasked to generate and distribute electricity to the people of Fiji at the lowest possible cost. FEA's vision is "energising our nation" and its mission that "it will provide clean and affordable energy solutions to Fiji and the Pacific. FEA aims to provide all energy through renewable resources by 2011".

Most of the electricity in Fiji, particularly for the main grid in Viti Levu, is generated from hydropower from two major sites, Monasavu and the newer Nadarivatu schemes, supplemented by mini hydro and diesel (the latter especially in drought years). A very small amount of electricity is produced from wind (wind turbines at Butoni) and increasingly from solar energy resources (distributed photovoltaics). The total installed capacity for the Viti Levu and Vanua Levu system as of 2010 was 205 MW, and about half the electricity generated was from hydro, and the other half from diesel and fuel oil. It should be noted that the last hydro power installation was only recently commissioned (2012), therefore there has been a reduction in peak demand met by diesel generation. FEA is investigating geothermal, biomass, and smaller hydro schemes, and is targeting to reach 90% renewable by 2015.

2.2.2 Tariff Structure

In the period from start 2008 to end 2012, tariffs had increased by 87% or almost double (for usage over 15MWh = 15,000kWh per month), including the rise in VAT from 12.5% to 15% on 1 January 2011. As VAT is also a cost to SPC (as are all other government taxes and charges), the tariffs used for analysis have included VAT.

More details of increases for the two FEA Commercial Tariffs are included in the analyses of Energy Use and Costs for each of the three SPC Suva locations. Note that there has been a small drop in tariffs as of 1 January 2013, most probably as a result of the new Nadarivatu hydro plant allowing lower use of diesel power supplementation to the Viti Levu grid.

Table 2.1: FEA Tariff Structures (as of 1st December 2012)

Category	Tariff (F$)	VAT 15% (F$)	Total (F$)
1. Domestic Consumption (kWh)			
a. 1 – 75 (subsidized)	0.172	0.0258	0.1978
b. > 75	0.3484	0.05226	0.40066
2. Commercial Consumption (kWh)*			
a. <14,999	0.42	0.063	0.483
b. > 15,000	0.44	0.066	0.506
3. Institutions & Street Lights	0.3484	0.05226	0.40066

Note: 1.Institutions include Primary and Secondary Schools and places of Worship.
2. US$1 = F$1.78 (average for 2012 www.oanda.com/currency/average)
3. Rates dropped on 1 January 2013

2.2.3 Electricity Demand

FEA supplies electricity to more than 140,000 domestic, 15,000 commercial and around 100 industrial customers (2009 figures) on only 3 islands in Fiji. These are Viti Levu, Vanua Levu and Ovalau. The rest of Fiji's islands are covered by the governments Rural Electrification Program.

Peak electricity demand was just over 150MW. Demand growth in Fiji was very high in the early days of FEA (30% per annum in early 1970s), but is now a more reasonable 5% per annum. Demand in 2005 was around 650,000MWh.

2.2.4 Emissions from Electricity Consumption

Unfortunately, FEA does not publish emission factors in their annual reports, however they do give the proportions of Renewable Energy (mainly Hydro, with up to 4% biomass, 1% wind and very little solar at this stage) and Thermal Energy (both Industrial Diesel and Heavy Fuel Oils). The biomass generation is from Independent Power Producers and is not covered by the FEA annual report.

Electricity production on the main island of Viti Levu, where Suva and the PIFS is located, was mostly from hydro electricity, with some thermal supplement (the amount of which depends on whether it was a wet or dry year – in the latter more thermal power was used). As a consequence emissions may vary from 0.3 kg CO_2/kWh in a "wet" year to 0.6 kg CO_2/kWh in a "dry" year. Other factors influencing emission factors include load growth, as the energy output from hydro is limited by rainfall and storage capacity, whereas increased energy output from thermal can be realised by the use of more Diesel or Fuel Oil. Thus emissions may also increase in years of heavy demand.

Unfortunately, at the time of writing, the annual report for 2012 was not available, however for the years 2008 – 2011, the proportion of Renewable to Thermal has dropped from 65%:35% in 2008, to 60%:40% for 2009 and 2011, and a low of 50%:50% for 2010. Diesel generation at the busbar results in emissions of around 0.80 kg CO_2/kWh, while "old" hydro is very low at around 0.01 kg CO_2/kWh. At the worst case scenario of 50:50% seen in 2010, emissions would be close to 0.4 kg CO_2/kWh.

There are emissions due to parasitic power losses in the plant, losses in transmission and distribution, and in running vehicles and other equipment. It is assumed this adds around 20%. This would give 0.5kg CO_2/kWh as the overall emission factor for the point of use. Not knowing figures for 2012, but recognising that new hydro has come online, this figure has been used.

3 SPC SUVA SITES AND AUDIT RESULTS

3.1 Lotus Building

The Lotus Building is situated in Nabua, Suva. SPCs Suva Divisions of EDD, PHD and ICT occupy the first and second (top) floor, both of which are individually metered by phase and floor. The ground floor is occupied by other tenants who are metered separately. The building has an emergency generator of 80 kW capacity in case of loss of power. Fuel tank capacity is unknown, so it has not been possible to estimate run time at full load assuming a full fuel tank. Actual possible run time also depends on the other tenants on site who are a variable factor over which SPC has no control. Fuel usage is estimated at 3 drums of 200 litre each, or 600 litre per annum in a year without cyclones.

Figure 3.1: Lotus Building Aerial View – north at top

(Note; Kings Rd top left, Matta Rd right, SPC Nabua entrance at top right)

The small rectangles seen on the top of the building are the condenser units of some of the larger split system air conditioners serving the top floor (2nd). The larger rectangles have a skylight "light tube" at the upper end also directing natural light to the top floor.

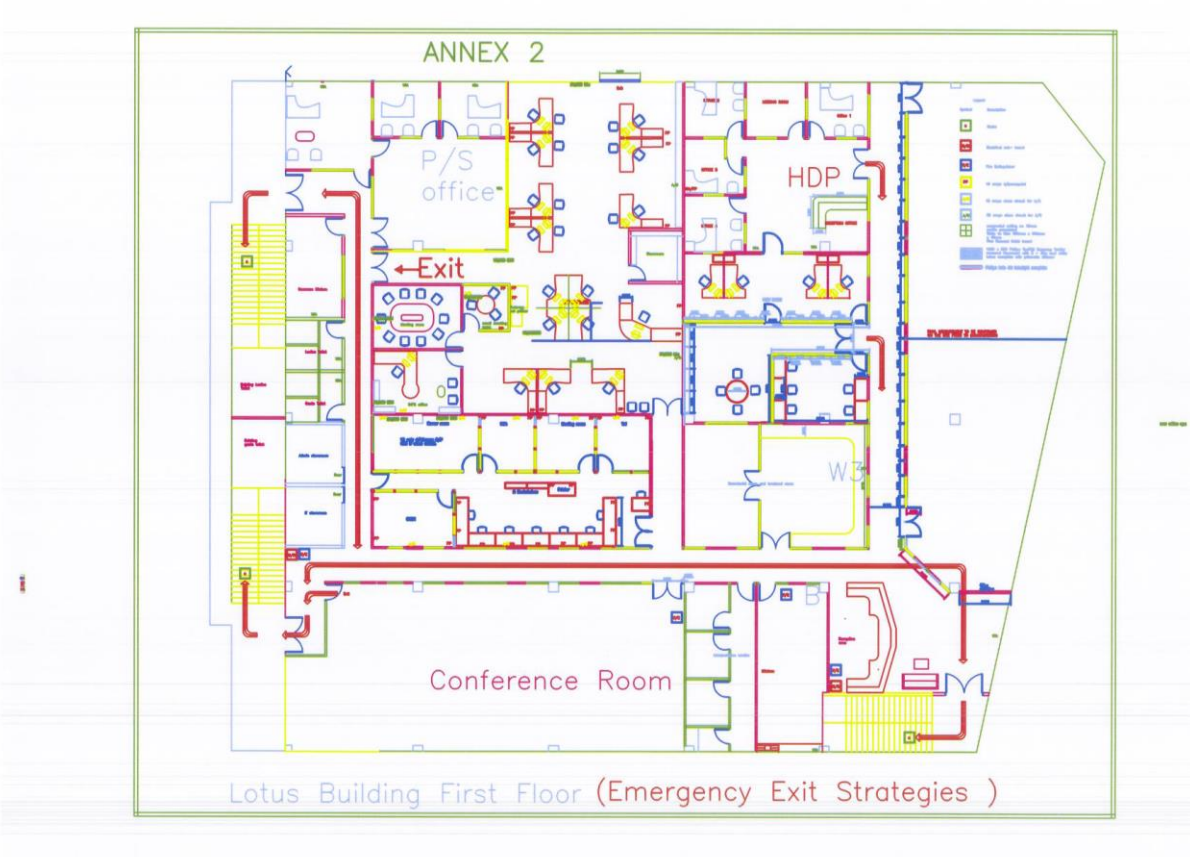

Figure 3.2: Lotus First Floor Layout

Figure 3.3: Lotus Second Floor Layout

3.1.1 Energy Usage and Cost

Energy usage from 2008 to 2012 is shown in Figure 3.2. As the billing for each of the floors was separate, floor totals were less than 14,999kWh (<15MWh) per month, so the rate charged was usually the lower of the split commercial tariff. Since price to the consumer (SPC) includes VAT, the tariffs quoted include VAT, which increased in January 2011.

While annual costs have increased substantially over this period (by 165% in 2012 from 2008), energy use increased only moderately up to 2011 (13% over 2008), but jumped markedly in 2012 (54% over 2008 most likely due to relocation of Nabua servers to Lotus). However, much of this cost increase can be attributed to tariff increases (2012 tariff increased by 75% since 2008).

This may have also been due to the SPC Nabua servers being centrally located in the Lotus Building.

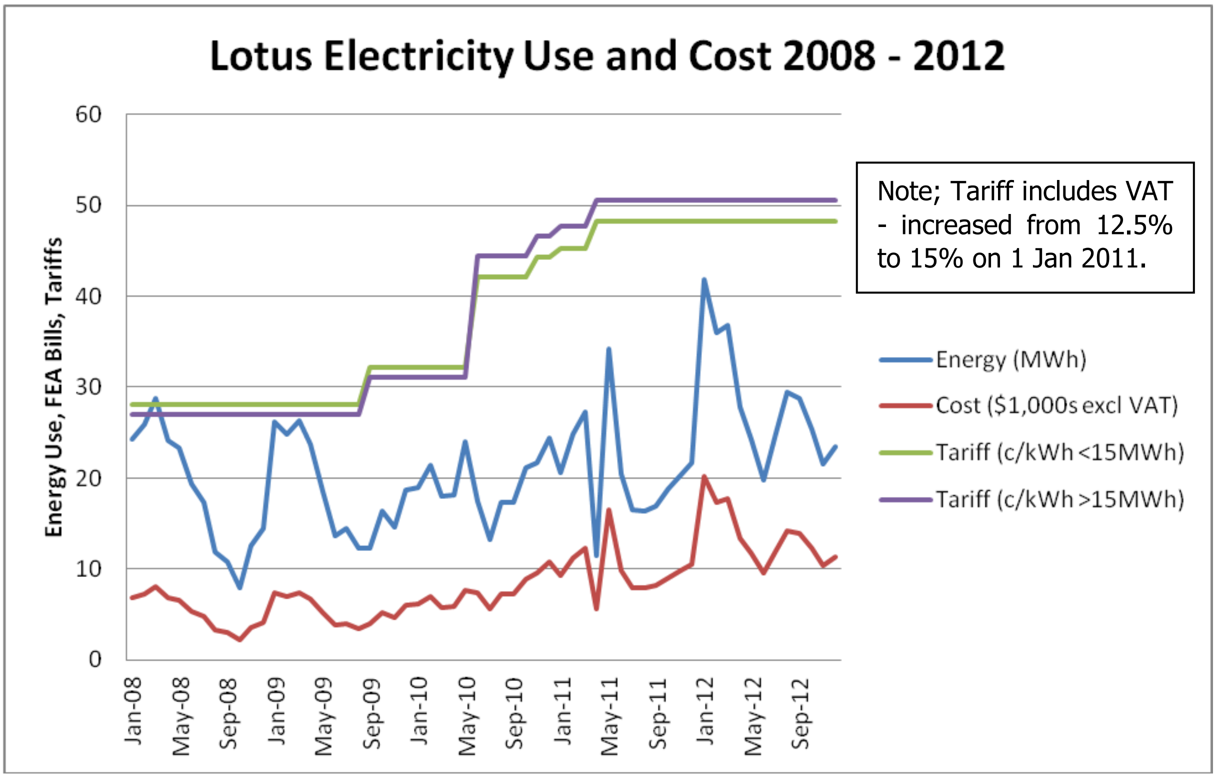

Figure 3.4: Lotus Electrical Energy Usage and Cost (2008 – 2012)

3.1.2 Energy Audit Results

The Lotus Building was audited in two sections in late 2012/ early 2013, the top or second floor was undertaken first, and the middle or first floor followed. These results are shown in Table 3.1, and the corresponding graph of Energy Use by device clearly shows that the major load in the Lotus building was as expected, from Air Conditioners (55%). However, it was noteworthy that the second largest load (19%) was from the SPC Suva Servers. Often ITC do not consider the energy usage of their equipment, as other factors are taken as more important, however worldwide with the increased use of ITC, this is becoming a concerning trend. Lighting was the 3rd largest user (11%), followed by office equipment (computers, UPSs, printers and copiers – total 8%).

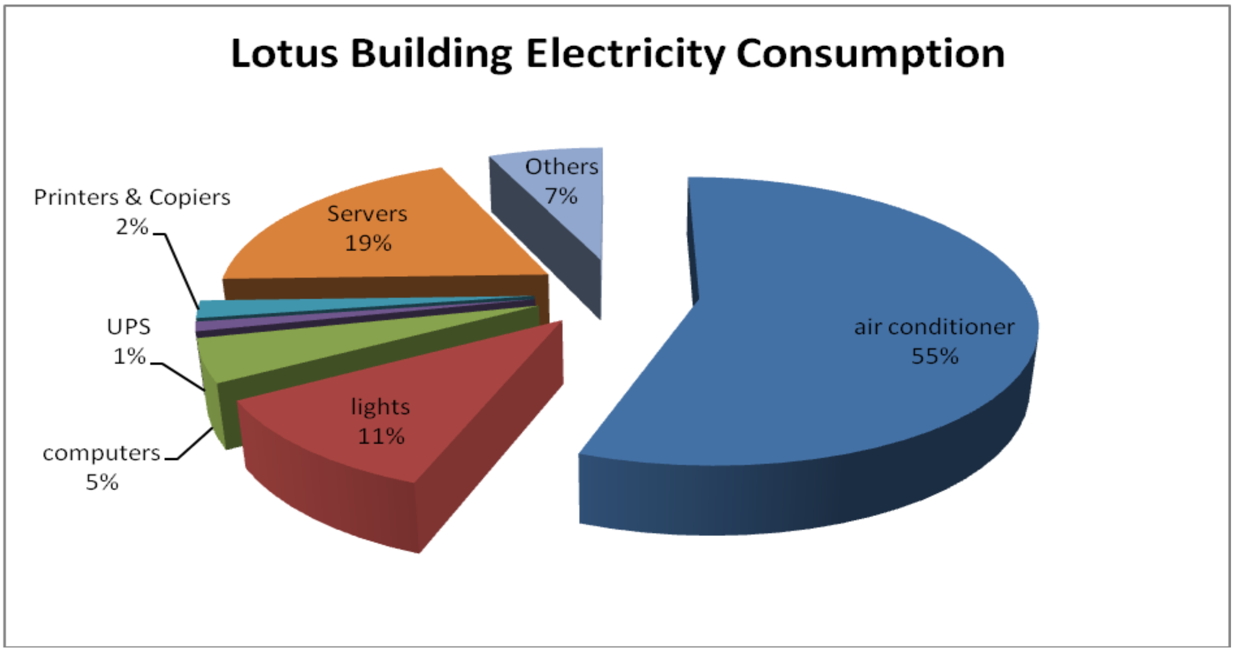

Figure 3.5: Lotus Electrical Energy Usage by device

Table 3.1: Energy Use for Lotus Building

Monthly Energy Use (kWh)	**Second (top) floor**			**First (middle) floor**			**Overall SPC LOTUS**		
	idle	load	total	idle	load	total	idle	load	TOTAL
air conditioner	145	6501	6646	89	5225	5315	234	11727	11961
lights	0	1157	1157	0	1214	1214	0	2371	2371
computers	64	594	657	39	344	383	103	938	1040
UPS	145	0	145	83	0	83	228	0	228
Printers & Copiers	119	118	237	73	114	187	192	232	424
Servers	29	860	889	1689	1763	3452	1723	2336	4059
Others	34	573	607	48	490	538	77	1350	1427
TOTAL	**536**	**9803**	**10338**	**2021**	**9151**	**11172**	**2557**	**18953**	**21510**

Units for this table are kWh/month (differences caused by rounding errors).

3.1.3 Conclusions and Recommendations

The Lotus Compound is the most modern of the 3 sites investigated. The major electrical energy user is Air Conditioning. There are a number of general steps to reduce this which are detailed in Section 5.

Building Envelope

- The roof is a light brown colour – painting with a reflective paint will decrease heat gain.
- The Second Floor should have roof insulation installed with a high R value.
- Both the first and second floor should have shading fitted on the eastern and western sides to reduce early morning and late afternoon heat gain from the sun.
- Being a relatively modern building, windows and some external doors are solid glass, however infiltration loss should be checked and reduced if possible (one outside door was open during my visit).
- Skylights are a way of introducing natural lighting to the building, however these should be shaded from direct solar radiation to prevent heat ingress (there are 3 pre-existing ones).

Energy Conservation

- Ensure air conditioner temperatures are not below 25°C. This should not be necessary if the building envelope is working well.
- If this is not cool enough, use fans as well (about an added 3°C cooling effect).
- Don't lower temperatures as this will not cool the room faster, and could be forgotten – lower temperatures can cause condensation and equipment/ building damage and ultimately, failure.
- Ensure ACs, lights turned off when no one in the room (especially overnight and on weekends).
- Shutdown computers overnight and on weekends. At least hibernate overnight. A shutdown each weekend is good policy for updates to be effected.
- Installation of power "strips" to enable a suite of equipment to be turned off with one switch.

Energy Efficiency

- As high use area ACs need replacing, preferentially convert these to High Efficiency Inverter ACs. These should be well installed with proper plinths, shades over condenser/ compressor units, and all electrics and pipework enclosed in ducting to prevent sun/ water damage.
- Given that the Servers for Nabua are now installed at Lotus, upgrades and replacement of this equipment to also consider energy efficiency as a priority.
- High efficiency fans to be installed to allow added cooling capacity via air movement rather than lowering temperature of ACs.
- Laptops to be used instead of desktops, and UPS "retired".
- All printers, scanners, photocopiers and other office equipment to only be replaced with "energy star" equipment which has good "sleep mode" facilities (low energy use when not in use).

Renewable Energy

- There is a large single roof area available for a solar PV array. Investigations should be made as to the strength of the roof to be able to support an array.
- Estimated roof area is at least 1,000m^2, and using standard PV arrays with efficiencies of 10% (including access walkways, means that a maximum of 100kWp is possible – allowing for airconditioners which are in the way, perhaps 75kWp could ultimately be installed).
- Addition of batteries and an "islanding inverter" would allow a "backup" supply for critical loads (not Air conditioning, but lights, fans and computers).

3.2 Nabua Compound

The Nabua compound is the original SPC Suva site, and dates back to the early days of SPC (1947). SPCs Suva Divisions of Land Resources; Operations and Management; and Education, Training and Human Development occupy the site. It is metered from a central area by phase only – there are no sectional or building splits in energy metering. The central switchboard/ metering area also houses a backup generator of 240kVA (nominal 200 kW) capacity. As with Lotus, fuel tank capacity is unknown, so it has not been possible to estimate run time at full load assuming a full fuel tank. Fuel usage is estimated at 3 drums of 200 litre each, or 600 litre per annum in a year without cyclones.

The site location is shown in the Google Earth photo following.

Figure 3.6: Nabua Compound Aerial View

(Note; North to top, Matta Rd left, sports fields right, Lotus building bottom left)

The compound has some two dozen or so buildings, many quite old. The main switchboard, metering and generator are housed in the small silver roofed building (#20) second on the right on the entrance road, nestled between two of the larger orange roofed buildings (see Figure 3.7 following).

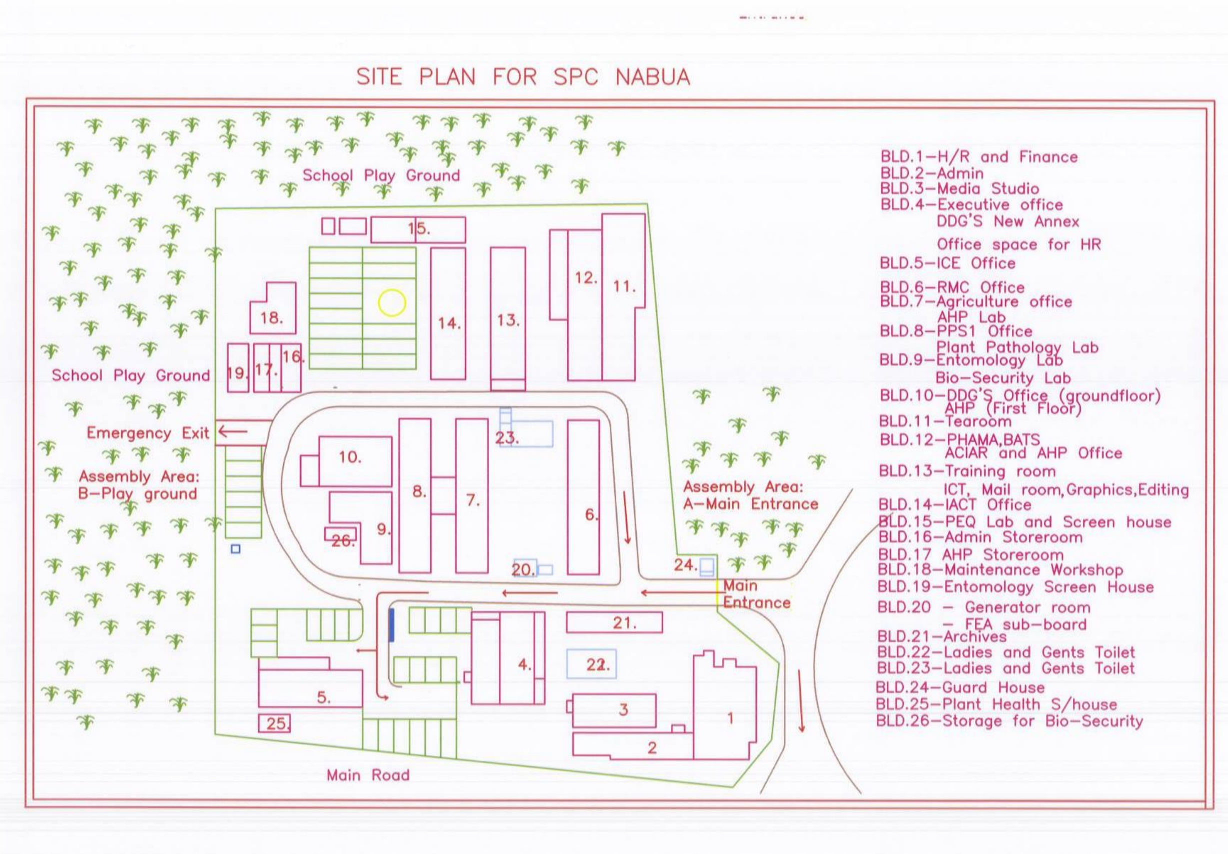

Figure 3.7: Nabua Compound Site Plan – north to the left

3.2.1 Energy Usage and Cost

Energy usage from 2008 to 2012 is shown in Figure 3.8. The energy use for the Compound has dropped over the years from an average of 40MWh per month to around two thirds that, compensating for the increase in tariff (2012 increased by 75% from 2008), so that costs have only increased by around 25%. The bulk of the bill at the end of 2012 is less than 14,999kWh (<15MWh) per month. In this case the rate charged was mostly made up of the lower of the split commercial tariff. Since price to the consumer (SPC) includes VAT, the tariffs quoted include VAT, which increased in January 2011.

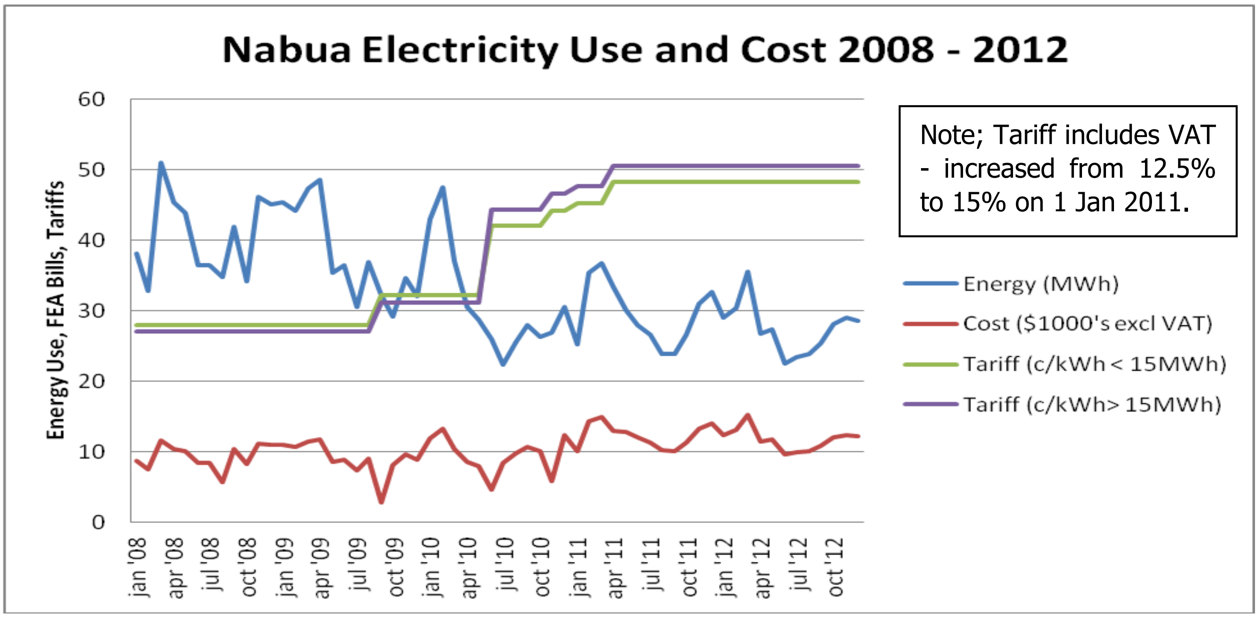

Figure 3.8: Nabua Electrical Energy Usage and Cost (2008 – 2012)

3.2.2 Energy Audit Results

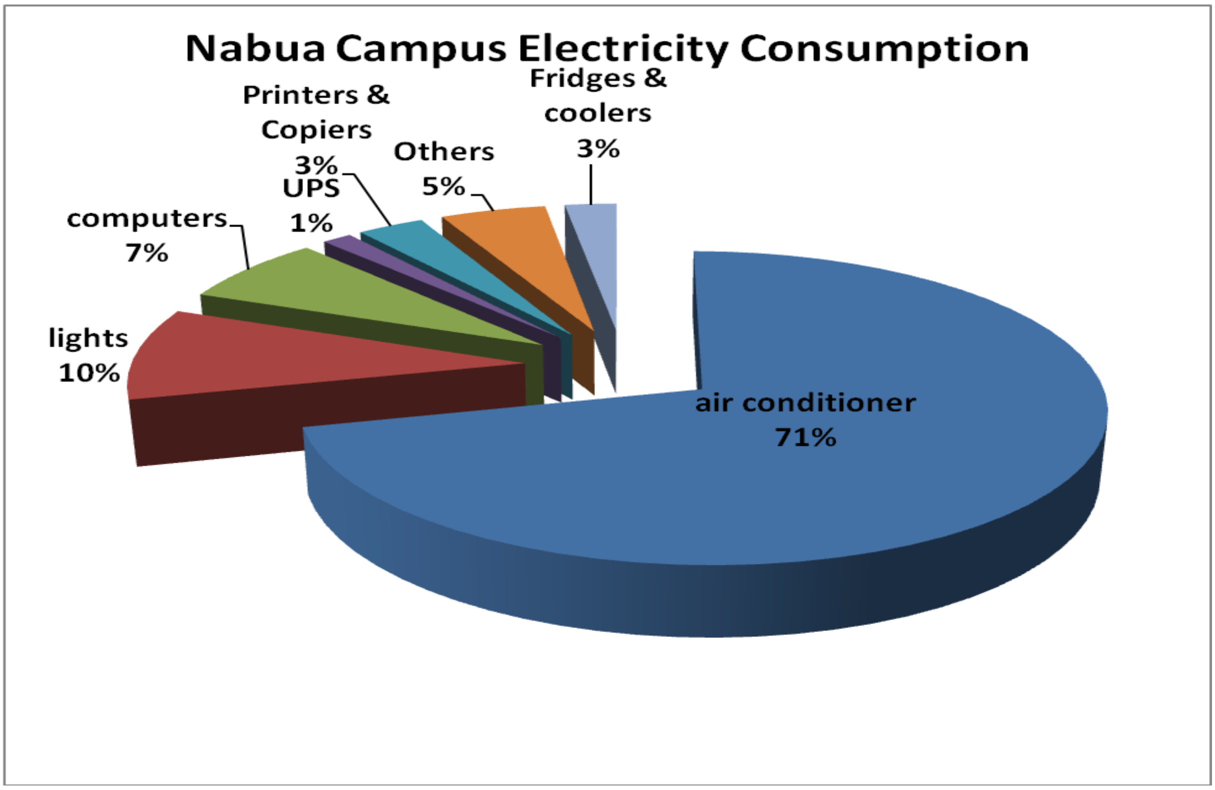

Figure 3.9: Nabua Campus Electrical Energy Usage by device

The Nabua Campus was audited in early 2013 and the results are shown in Table 3.2. The corresponding graph of Energy Use by device clearly shows that the major load on the Campus was the same as for the Lotus, being Air Conditioners (71%), even greater than for the Lotus. The second largest load (11%) was from office equipment and was closely followed by lighting. There were no servers on the Campus, as these were all shifted to the Lotus building.

Table 3.2: Energy Use for Nabua Campus

Monthly Energy Use (kWh/month)	**idle**	**load**	**TOTAL**
air conditioner	410	19685	20095
lights	0	2767	2767
computers	138	1876	2015
UPS	222	173	395
Printers & Copiers	372	514	886
Others	121	1277	1397
Fridges & coolers	62	620	681
TOTAL	**1324**	**26911**	**28236**

3.2.3 Conclusion and Recommendations

The Nabua Compound is one of the oldest of the 3 sites investigated. The major electrical energy user is Air Conditioning as with the other sites, but is the highest of the three as a proportion. This is unsurprising as the surface to volume ratio of the 24 or more buildings is high. There are a number of general steps to reduce this which are detailed in Section 5.

Building Envelope

- The most obvious solution would be to redevelop the site with fewer, but larger and more energy efficient buildings.
- Painting all roofs with a reflective paint will decrease heat gain.
- All buildings should have roof insulation installed with a high R value.
- All buildings should have shading fitted on exposed eastern and western sides to reduce early morning and late afternoon heat gain from the sun.
- Being old buildings, many windows are louvred, and infiltration loss may be high. Replacement with higher quality louvers or casement windows that seal well is a priority.
- Skylights are a way of introducing natural lighting to the building; however these should be shaded from direct solar radiation to prevent heat ingress.

Energy Conservation

- Ensure air conditioner temperatures are not below 25°C. This should not be necessary if the building envelope is working well.
- If this is not cool enough, use fans as well (about an added 3°C cooling effect).
- Don't lower temperatures as this will not cool the room faster, and could be forgotten – lower temperatures can cause condensation and equipment/ building damage and ultimately, failure.
- Ensure ACs, lights turned off when no one in the room (especially overnight and on weekends).
- Shutdown computers overnight and on weekends. At least hibernate overnight. A shutdown each weekend is good policy for updates to be effected.
- Installation of power "strips" to enable a suite of equipment to be turned off with one switch.

Energy Efficiency

- As high use area ACs need replacing, preferentially convert these to High Efficiency Inverter ACs. These should be well installed with proper plinths, shades over condenser/ compressor units, and all electrics and pipework enclosed in ducting to prevent sun/ water damage.
- High efficiency fans to be installed to allow added cooling capacity rather than lowering temperature of ACs.
- Given that the highest energy use for Servers is at SOPAC, upgrades and replacement of this equipment to also consider energy efficiency as a priority.
- Laptops to be used instead of desktops, and UPS "retired".
- All printers, scanners, photocopiers and other office equipment to only be replaced with "energy star" equipment which has good "sleep mode" facilities (low energy use when not in use).

Renewable Energy

- There is some roof area available for a solar PV array. Investigations should be made as to the strength of the roofs to be able to support an array. There are many old trees which should be retained for shade, so siting is not straightforward.
- Estimated roof area is at least 2,500m^2, however due to shading constraints usable area is only 1,500m^2. Using standard PV arrays with efficiencies of 10% (including access walkways, means that a maximum of 150kWp is possible – allowing for roof obstructions which are in the way, perhaps 100kWp could ultimately be installed).
- Addition of batteries and an "islanding inverter" would allow a "backup" supply for critical loads (not Air conditioning, but lights, fans and computers).

3.3 SOPAC Compound

The SOPAC compound became part of the SPC in 2011, however many of the buildings date back to SOPACs beginnings in 1972, in the era of cheap petroleum and energy. SOPACs Technical Divisions of Oceans and Islands, Water and Sanitation, and Disaster Reduction occupy the site, which is shared by the Fiji Department of Mineral Resources. It is metered by phase from a central area and one subsidiary area. The central switchboard/ metering area also houses a backup generator of 150kVA (120 kW prime) capacity. Fuel tank capacity (375 litre) enables this generator to operate at full load for 8 hours (assuming a full fuel tank). The backup is run on average twice per month for 2 hours at a time for testing and to cover FEA power cuts. Annual fuel use is estimated at 6 drums of 200litre.

The site location is shown in the Google Earth photo following.

Figure 3.10: SOPAC Compound Aerial View

(Note; Mead Rd bottom left)

The compound has some dozen or so buildings, many quite old. The main switchboard and metering are located near the middle of the larger area.

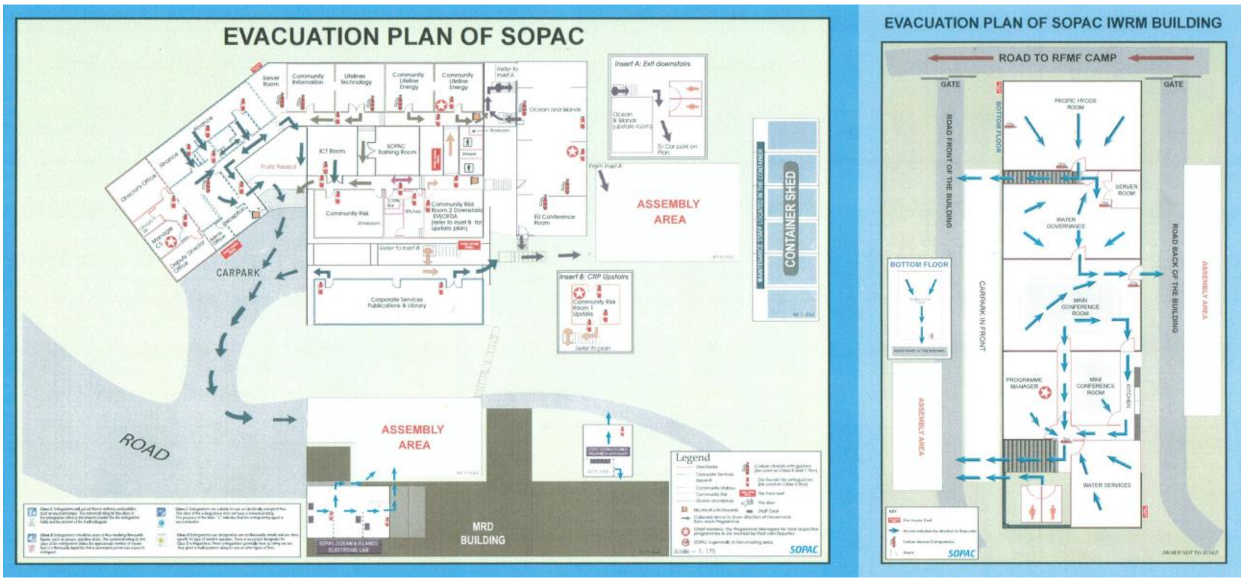

Figure 3.11: SOPAC Compound Site Plan – North of main area to top right

3.3.1 Energy Usage and Cost

Electrical energy usage and cost from 2008 to 2012 is shown in Figure 3.8. The energy use for the Compound rose over the years from an average of a little over 20MWh per month, peaking to an average of close to 27MWh per month in 2011 (close to 25% increase). Costs however, have increased from an average of $5,000 per month to around $11,000 per month (over 130% increase), largely due to tariff and VAT increases.

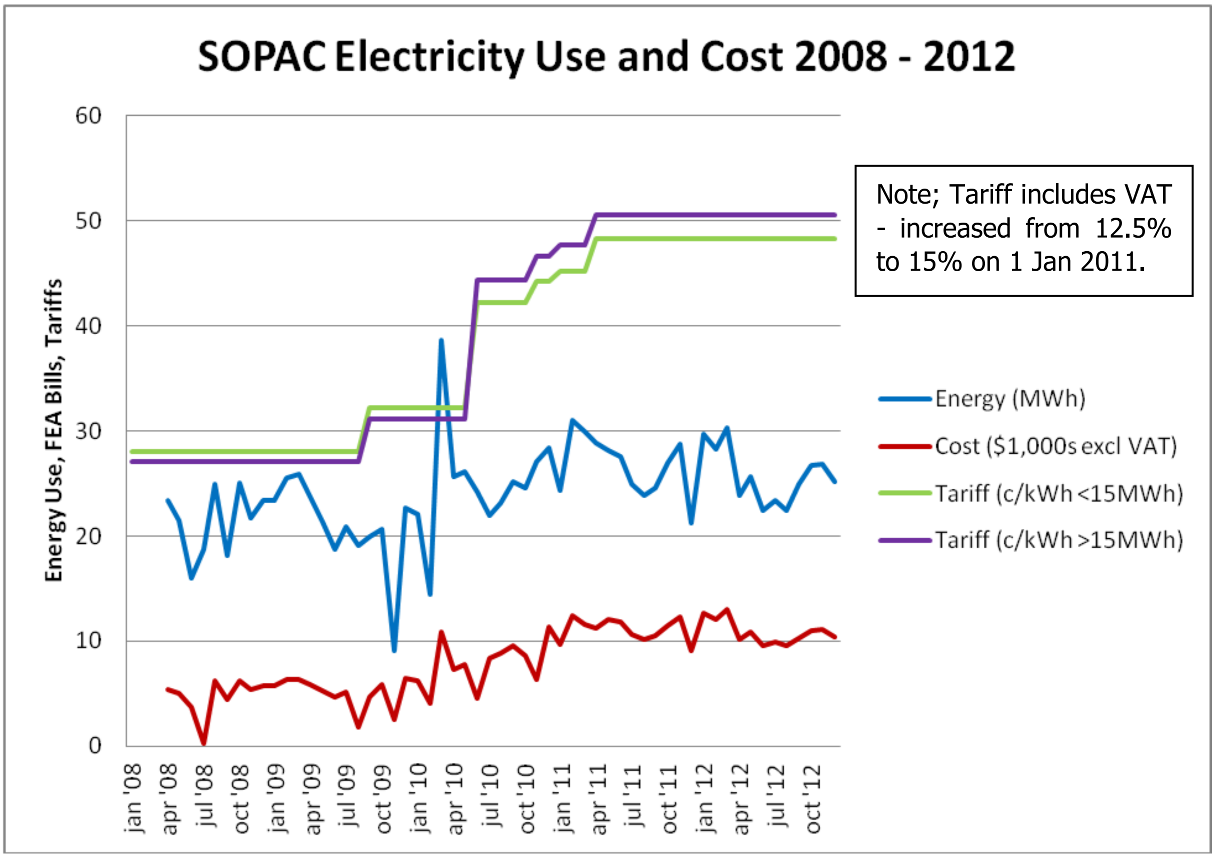

Figure 3.12: SOPAC Electrical Energy Usage and Cost (2008 – 2012)

3.3.2 Energy Audit Results

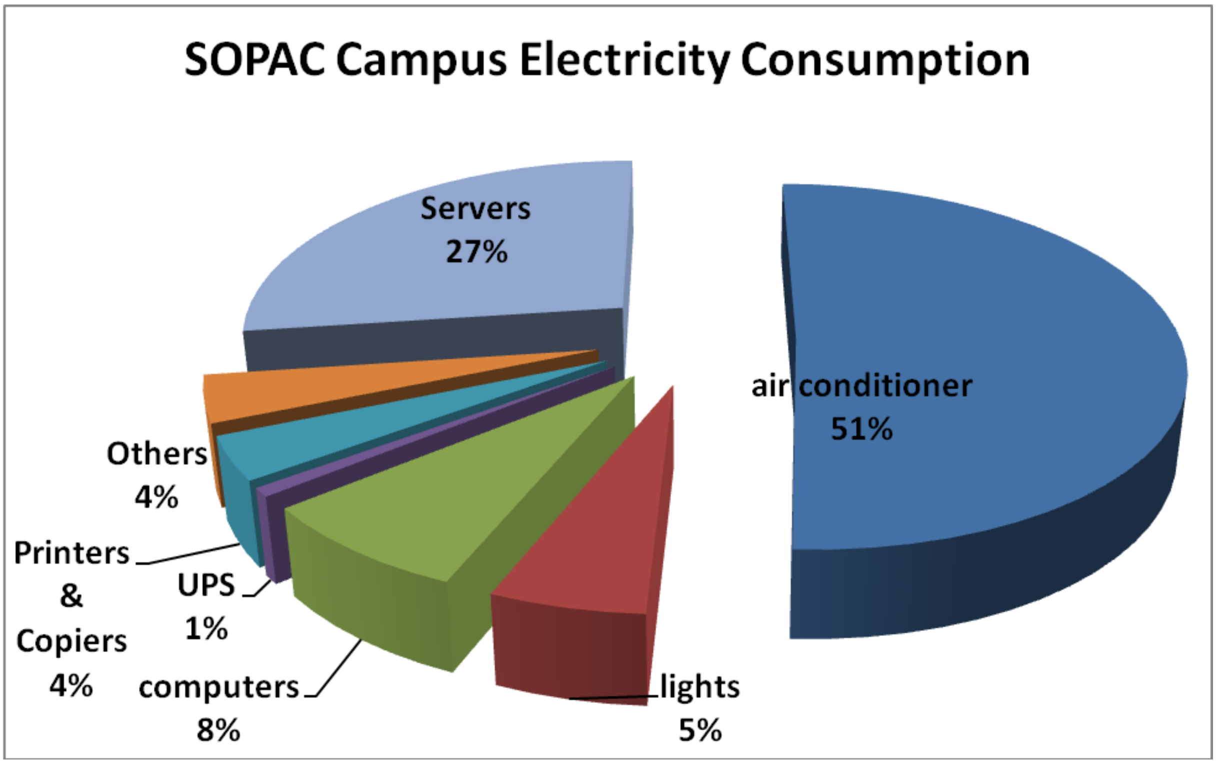

Figure 3.13: SOPAC Campus Electrical Energy Usage by device

The SOPAC Campus was audited in early 2013 and the results are shown in Table 3.3. The corresponding graph of Energy Use by device clearly shows that the major load for the Campus was the same as for the Nabua Campus and Lotus Building, being Air Conditioners (51%), the lowest of the 3 compounds. The second largest load (27%) was for the servers, followed by office equipment (13%), and lastly by lighting (5%). Servers and Office Equipment together total 40% of electricity consumption.

Table 3.3: Energy Use for SOPAC Campus

Monthly Energy Use (kWh/month)	**idle**	**load**	**TOTAL**
air conditioner	312	12111	12423
lights	0	1334	1334
computers	117	1835	1951
UPS	188	0	188
Printers & Copiers	388	539	928
Others	112	890	1003
Servers	0	6641	6641
TOTAL	**1118**	**23350**	**24468**

3.3.3 Conclusion and Recommendations

The SOPAC Compound is one of the oldest of the 3 sites investigated. The major electrical energy user is Air Conditioning as with the other sites, and the energy use per unit of floor area is the highest of the three by a big margin. This is unsurprising as most of the windows are louvres, the roof is dark and the ceiling insulation suspect. As with Nabua, the surface to volume ratio of the many buildings is high. Also, unlike the other 2 SPC sites in Suva, energy use has increased over time.

There are a number of general steps to reduce this which are detailed in Section 5.

Building Envelope

- As with Nabua, most obvious solution would be to redevelop the site with fewer, but larger and more energy efficient buildings.
- Painting all roofs with a reflective paint will decrease heat gain.
- All buildings should have roof insulation installed with a high R value.
- All buildings should have shading fitted on exposed eastern and western sides to reduce early morning and late afternoon heat gain from the sun.
- Being old buildings, many windows are louvred, and infiltration loss may be high. Replacement with higher quality louvres or casement windows that seal well is a priority.
- Skylights are a way of introducing natural lighting to the building; however these should be shaded from direct solar radiation to prevent heat ingress.

Energy Conservation

- Ensure air conditioner temperatures are not below 25°C. This should not be necessary if the building envelope is working well.
- If this is not cool enough, use fans as well (about an added 3°C cooling effect).
- Don't lower temperatures as this will not cool the room faster, and could be forgotten – lower temperatures can cause condensation and equipment/ building damage and ultimately, failure.
- Ensure ACs, lights turned off when no one in the room (especially overnight and on weekends).
- Shutdown computers overnight and on weekends. At least hibernate overnight. A shutdown each weekend is good policy for updates to be effected.
- Installation of power "strips" to enable a suite of equipment to be turned off with one switch.

Energy Efficiency

- As high use area ACs need replacing, preferentially convert these to High Efficiency Inverter ACs. These should be well installed with proper plinths, shades over condenser/ compressor units, and all electrics and pipework enclosed in ducting to prevent sun/ water damage.
- High efficiency fans to be installed to allow added cooling capacity rather than lowering temperature of ACs.
- Laptops to be used instead of desktops, and UPS "retired".
- All printers, scanners, photocopiers and other office equipment to only be replaced with "energy star" equipment which has good "sleep mode" facilities (low energy use when not in use).

Renewable Energy

- There is reasonable roof area available for a solar PV array. Investigations should be made as to the strength of the roofs to be able to support an array.
- Estimated useable roof area is at least 500m^2, and using standard PV arrays with efficiencies of 10% (including access walkways, means that a maximum of 50kWp may be possible).
- Addition of batteries and an "islanding inverter" would allow a "backup" supply for critical loads (not Air conditioning, but lights, fans and computers).

4 ELECTRICAL ENERGY REDUCTION TECHNIQUES

There are a number of techniques to reducing electrical energy use (and hence GHG emissions). These are normally undertaken in the sequence shown below, as the initial steps are usually quicker and cheaper to implement. In addition, later steps "build" on the former, and if swapped may lead to overinvestment. These techniques can also be adapted for reducing GHG emissions in other areas, such as for vehicles.

4.1 Set up baseline energy use

This is undertaken using an energy audit, with checks against billing (FEA metering). In addition the following monitoring should be installed as a first step in the implementation phase:

- Individual appliances identified as large energy users should have energy monitoring permanently installed (such as ACs with the SiCleanEnergy Power Usage Meter).
- Various buildings, departments or sections can have recording energy meters fitted to their switchboards (such as the Efergy E2 Classic 2 energy meter) to give indicative feedback on energy use).
- Lighting levels can be ascertained using a light intensity meter (so lighting levels are at least as good after retrofit with more efficient lighting).
- Temperature settings of Air Conditioners can be noted (if necessary, temperature logging can be undertaken using a recording Temperature/ Humidity meter such as an Extech RHT20).

4.2 Implement Energy Conservation Measures

Energy Conservation is about how existing equipment is used, and as such does not incur a large capital cost, since it is more about behavioural change. Examples of this include;

- Ensure air conditioner temperatures are not below 25°C. Lower temperatures can lead to condensation if warm moist air is introduced, leading to mould and corrosion, and ultimately building or equipment failure.
- If this is not cool enough, use fans as well (about an added 3°C cooling effect). Don't reduce temperature as this will not cool faster, the air conditioner has a thermostat which means it works flat out until reaching the correct temperature, then cuts off. Lower settings may be forgotten leading to energy loss and future problems as detailed above.
- Ensure ACs, lights turned off when no one in the room (especially overnight and on weekends).
- Shutdown computers overnight and on weekends. At least hibernate overnight. A shutdown each weekend is good policy for updates to be effected.
- Installation of power "strips" to enable a suite of equipment to be turned off with one switch.

4.3 Upgrade Building Envelope

The envelope which is being cooled, lit and worked in should be as efficient as possible to avoid unnecessary use of energy. Most people can readily understand that you would not fix a leaky water tank by adding another water source, but would plug the leak. Similarly one should not fix a bad building design by adding more air conditioning or lighting. The types of areas that should be considered include:

- Improvements to roof and ceiling insulation. This is where most head ingress occurs in the tropics.
- Ensuring roof colour is light, or if upgrading roof, use reflective surfaces (these should be mould proof in the tropics, as mould is often darker, spoiling the reflectivity and increasing heat absorption).
- Ensure east and west walls are shaded (especially the west). Low sun can still heat a building.
- Ensure good flow through ventilation, fans (especially if the building is not air-conditioned, and for power outages when natural ventilation must be used).
- If air conditioned ensure the building is well sealed against infiltration.
- Use natural lighting where possible (install skylights).

4.4 Implement Energy Efficiency measures

Energy Efficiency is about replacing inefficient equipment with modern efficient equipment (high number of energy stars"). This incurs a capital cost, but payback if often less than 2 – 3 years and almost always < 5 years. For comparison purposes of energy use, see www.energyrating.gov.au

- ACs are usually the largest energy consumer (replace with inverter ACs with high EERs)
- Computers, printers, servers usually next largest (replace with laptops, energy star)
- Lighting is significant (use CFLs or LED lighting)
- Fans should be used in preference or in addition to ACs (fit energy efficient fans)
- UPSs not needed for computers if they are laptops. Small standalone RE for printers, servers.

4.5 Implement Renewable Energy measures

Demonstration Stand-alone RE system at a chosen site – this will not reduce GHG much, but with water storage and a pump gives the site restrooms, water and laptop power in case of emergency, as well as serving as a good demonstration of this technology.

A larger demonstration Grid Connected PV system – such as covered parking or the canopy over an entrance. It is suggested that a solid PV canopy could be installed, giving both shade and weather protection, perhaps 10 kWp could be installed. Good sites are high profile areas where visitors first approach the site.

Should these smaller demonstrations prove economic and practical, there is ample roof area to expand the use of PV generated electricity to supplement SPC electricity use, as previously detailed.

4.6 Evaluate the Programme

It is recommended that more detailed monitoring be undertaken in 2013, to plug holes in the data. Thereafter, annual audit checks should be then carried out, to track electrical energy use reductions as programs are implemented.

This should not be so difficult after the installation of the energy monitoring equipment as detailed in Section 4.1. This also has the advantage of allowing Site Energy Managers to obtain more direct feedback, as well as Financial Personnel, Section or Division Managers and Employees. This assists Energy Conservation and Energy Efficiency measures.

5 PROGRAMME FINANCIAL ANALYSIS

While there are many ways to reduce energy costs, it is difficult to choose where to start first. This can be a combination of what is easy, or what is cheap, or what will make the greatest impact, or perhaps most importantly, what has the quickest payback. Total present load is around 900MWh per annum (say 1000MWh to round it off for our purposes here), of which air conditioning is over half.

The table below sets out estimates of the potential savings that can be achieved by targeting four main areas (comprising 8 programmes) to assist with electricity reduction; Monitoring, Energy Conservation, Energy Efficiency (building envelope, air conditioners, servers, office equipment, lights), and Renewable Energy installations (grid connected photovoltaic systems).

All costs below are in Fiji Dollars,

Table 5.1: Costs and Annual Savings of proposed Programmes

	Project	Cost to Implement ($1000s)	Annual Savings (MWh)	Cost Savings ($1000s)	Internal Rate of Return	Payback period (years)	CO_2e avoided (tonne)
1	Monitoring	$20	25	$12.5	62.5%	1.6	12.5
2	Conservation Program	$25	50	$25	100%	1.0	25.0
3	Building Envelope	$250	100	$50	19.4%	5.0	50.0
4	Air Conditioners	$480	120	$60	10.9%	8.0	60.0
5	Servers	$300	60	$30	7.8%	10.0	30.0
6	Office Equipment	$175	45	$22.5	11.4%	7.8	22.5
7	Lights	$100	50	$25	24.7%	4.0	25.0
8	PV System (225kWh)	$900	250	$125	12.6%	7.2	125.0
	TOTAL	**$2250**	**700**	**$350**	**14.5%**	**6.6**	**350.0**

Assuming an electricity cost at the upper range of F$0.50/kWh (VAT included), and an emission factor of 0.50 kg CO_2/kWh (or 0.5 tonne CO_2/MWh).

Payback Period calculated as a undiscounted payback (Implementation Cost/ Annual Savings).

IRR calculated using the following website, over an 20 year period, assuming savings do not increase (which is unlikely, as electricity prices are likely to inflate over the years);

www.engineeringtoolbox.com/internal-rate-of-return-irr-d_1235.html

IRRs should therefore be better than calculated here.

5.1 Programme Details

The programmes outlined below have been chosen to reduce SPCs energy use by about 50%; however this will only occur if all are implemented. By far the most important programmes relate to Air Conditioning, and these are the first 4 shown below. It is difficult to estimate the exact split of savings from each of these 4, however by implementing all 4 a 50% saving is within the realms of possibility, however good installation, maintenance and operation will be required to realise this.

5.1.1 Monitoring

As part of increasing awareness, feedback needs to be implemented so that occupants, Section Heads, Accounts and Building Energy Managers can see the results of their actions. Each air conditioner should have a Power Usage Meter fitted, and each building should have a total energy Meter installed. There are around 150 ACs and 50 buildings. The PUMs are around F$60 each, and the Building Meters are around F$200 each. It is estimate awareness could save 2.5% of the AC load, or 25MWh/ annum.

One very important area which requires separate monitoring is the Server areas. This was very difficult for the energy auditors to estimate, as it was not possible to shut these areas down. A Building Meter should be installed for the Server areas at Lotus and SOPAC.

5.1.2 Energy Conservation:

It is assumed that with changes in occupants habits, raising of AC temperatures, turning off equipment when not present, around 5% of the AC load can be saved, or 50MWh/ annum. In order to bring employees "on board", in conjunction with monitoring, funds for publications and staff training have been set aside to reinforce EC concepts and implementation.

5.1.3 Building Envelope

This is one of the most important areas of energy efficiency, since in many cases buildings that were not designed to be air conditioned are having AC fitted to them. Consequently the buildings are "leaky" in a number of ways, through radiative, conductive and convective heat gain. The Lotus building is the most modern building, and has the lowest AC load per unit area (even with the largest server system). The older buildings in Nabua and SOPAC compounds will be difficult and expensive to retrofit, and one wonders if newer more energy efficient buildings would not be the best solution in the long term. This however, is outside the scope of this consultancy.

The two major sources of heat gain are; from solar heating through the roof, west and east walls, in that order; and from loss of cold dry air from inside, and absorption of warm moist air from outside (infiltration).

Insulation and ventilation of roof spaces and shading of western and eastern walls, plus replacement of leaky louvre windows can halve cooling loads on poor sites. It is assumed that overall around a fifth of the cooling load can be reduced (100MWh per annum).

5.1.4 Air Conditioning

Many old style airconditioners have an EER of only a little over 2. With age, and corrosion of the condenser and evaporator fins, this EER is reduced. Modern Inverter ACs have EERs of 4 or more, and being more expensive models, usually come with corrosion protection on the fins, and so will hold the EER for longer, with slower degradation and loss of efficiency.

In addition, the EER improvement is only part of the story. The method of operation of an Inverter AC is such that it "matches" its output to the air conditioning load, whereas the older style "full on, full off" operation with thermostat control approximates a match – the short answer to the long story is that there is energy saving here as well. In addition, shading of the condenser unit from the sun and protection from rain improved performance and increased longevity. Tests in RMI showed that while a halving of energy use was expected with a doubling of EER, in fact only one third the energy was used. Lifetimes of 10 years are expected, against a maximum of 5 years for a cheap unit.

It is assumed that 120 ACs will be replaced (not inverter already), at a cost of F$5000 each installed (with shade, and ducting to cover piping, insulation and electrical cables to improve efficiency and reduce losses). If this is done when ACs require replacement, we can subtract the cost of the ordinary AC from this (say F$1000), plus we have doubled the lifetime of the unit by buying good quality and installing it properly, reducing labour costs as well as material costs.

It is conservatively estimated that around a quarter of the cooling load can be saved (120MWh per annum). Paybacks of better than 8 years are expected if the oldest, most inefficient ACs are replaced first.

5.1.5 Servers

This was the surprise in the audit; however it has been found that in the average business, servers use is consuming some 10% of electrical energy, so SPC Suva is not far removed from the average. It is suggested that the Lotus and SOPAC server sites be fully monitored, as it was difficult for the auditors to accurately measure energy use in this area, and estimates were made. Monitoring should also include ACs for the server rooms.

When servers and their UPS are being upgraded or replaced, energy efficiency should be considered to be as important as other features, since this also impacts on the air conditioning load (and hence the energy used for cooling as well). With judicious choice, data centre energy use can be halved (60MWh annum).

There are a number of energy conservation measures that can be used as well, such as raising AC temperatures to 25°C in the server rooms – a common "mistake" by ICT personnel is to overcool server rooms, leading to high energy use and condensation problems, which often shortens equipment lifetimes, contrary to common beliefs. See reference "Improving Energy Efficiency of Server Rooms".

5.1.6 Office Equipment

There were a total of 174 desktop computers (38 Lotus, 80 Nabua, 56 SOPAC), or around 55% of all computers at the 3 sites. Total computing energy use was 60MWh/ annum and UPS was 10MWh/ annum. It is estimated around 50MWh of the computing energy use was from desktop computers.

By converting all desktops to laptops, it is possible that UPSs can be removed, and savings made of around 67-75% of energy used (depending on how old the desktop was that was being replaced). Taking a conservative approach, some 35MWh could be saved on computing, and 10MWh on UPS, a total of 45MWh.

The cost of a standard laptop is in the order of F$4,000, so the total cost of replacing all desktops is substantial. However if upgrading older desktops and printer/copiers with energy efficient laptops is adopted at the time replacement is required, then the cost is reduced by the cost of the new desktop (and UPS) that would have been required. For the purposes of this exercise, it is assumed that only an additional F$1,000 is required as a result (since a new desktop is around F$2,200, and a 500W UPS is F$800 over a good quality passive surge arrestor). Issues of portability and convenience may be the deciding factor, not energy use alone.

It is assumed that for the odd occasion that power cuts occur, that the loss of the monitor is acceptable, and that since FEAs power quality is better than in smaller PICs, (where many laptops have operated successfully for years without power surge protection) no UPS backup is required. If added protection is required, passive surge arrestors (zero energy use) can be used instead of UPSs.

5.1.7 Lights

It is estimated that there are 1000 fluorescent tubes spread over the 3 sites. Average length of time they are operating is 8h/day, for 22 days/month (this equals around 2000h/ annum). Assume F$100 per 15W tube installed (prices for quality products are dropping – this could be halved in a few years time).

With a 15W LED tube replacing a 1200mm 36W tube (with 9W ballast – total 45W), savings of 30W (or 66.7%) are possible for each fluorescent tube replaced with LED. Similar percentage savings are possible for 600mm tubes. This translates to 53.4MWh per annum.

The main advantages of LED tube lamps are; no mercury, long lifetimes of 50,000h or more (if thermal dissipation is good), and hence lower labour costs for relamping. Payback with current LEDs is around 4 years. An ordinary fluorescent with 10,000h life requires replacing every 5 years. The LED lamp should last 25 years.

5.1.8 Photovoltaic System

The combined roof area of the 3 sites would allow a maximum of 225kWp of photovoltaic arrays. This assumes the roofs are capable of supporting the load, and are cyclone rated. Note that this is sized to produce about a quarter of SPCs present energy use, and if all the EC and EE programmes are successfully implemented, half of SPCs future energy use.

A ballpark figure of F$4 per Peak Watt was used including PV modules, array frames, inverters, wiring and trunking, earthing and safety switches and also installation. This is a current cost, and has been falling in recent times by around 30% per year (last 5 years).

A conservative value of 3 peak sun hours per day has been used (Suva is on the wetter side of Viti Levu) to calculate annual energy output. This allows for some shading, and sub optimal siting of the arrays (not true north azimuth, nor 16 degrees altitude). Generation of around 250MWh per annum is conservatively estimated.

Avoided CO_2e range is based on 0.3 – 0.6 kg CO_2e/kWh of energy displaced.

There is also a possibility of using battery storage at each of the 3 sites to allow "islanding" to occur in the event of power outages. This entails the use of special solar inverters which can disconnect the system from the grid when power fails, and run as a "stand-alone" system. However, efficiency improvements need to be made well before this is considered, and essential services (lights, water, computing, and fans) separated from non-essential (ACs, heating appliances). This could be the subject of further investigation once this program has been implemented and SPC Suva's energy use reduced.

5.2 Priority of Programmes

If one is to take shortest payback period (and highest IRR), then the Conservation Program and Monitoring are at the top, closely followed by building envelope improvements. These are important to undertake before Air Conditioning upgrades, since they reduce AC cooling loads, and so smaller AC are required to achieve the desired result, reducing both capital and running costs. Note that an efficiency improvement from installation of new equipment lowers AC requirements as well.

Following the successful conclusion of these programs, AC upgrades can be implemented.

The most costly programs in terms of payback (and lowest IRR), are the Server upgrades and Office equipment, and so it is envisaged these would occur last, along with the Renewable Programme.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Unsurprisingly, the major use of electricity across all 3 sites was for Air Conditioning (59.9%). However, the Nabua campus was the worst offender (71%), followed by Lotus and lastly SOPAC. It was not expected that the second largest user of electricity would be the Servers (14.4%) which are situated at the Lotus Building (19%) and SOPAC (23%). There are none at Nabua. The third largest is office equipment (10.9% - Computers 6.7%; UPS 1.1% and Printers and Copiers 3.0%). Fourth largest is lighting (8.7%) and lastly others (6.1% fridges, freezer, water coolers, kitchen equipment, small miscellaneous).

6.2 Recommendations

The buildings at Nabua and SOPAC are older buildings not designed for air conditioning, and so these buildings require most attention for reduction of "leakiness" in terms of heat ingress. This should have a major impact in terms of reducing energy use. A combination of building improvements, and AC upgrades will lead the impact, together with Energy Conservation measures.

Surprisingly, the servers at SOPAC and Lotus are the second highest energy use. More detailed monitoring is required here to validate this and track measures to reduce electricity use. An upgrade of server equipment over time is required.

Office equipment and lighting upgrades complete the actions required. Again, implementation can be staggered to reduce workload and allow costs to be spread over time.

7 ANNEXES

7.1	**ANNEX A: REFERENCES**

7.1 Annex A: References

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