NAURU UTILITIES CORPORATION
Aiwo District, Republic of Nauru

Technical Evaluation and Assessment Study of NUC Power Generation and Distribution Systems

In support of the development of the Nauru Energy Road Map

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1 Introduction

The Government of the Republic of Nauru (RON) with support from the German Technical Cooperation (GIZ) and the International Renewable Energy Agency (IRENA) are in the process of developing an Energy Road Map for the country. An important stakeholder in the development and the implementation of the Energy Road Map is the Nauru Utilities Corporation (NUC), the government owned electricity, water and fuel entity.

Following a request from the NUC through the GIZ office in Suva, the Pacific Power Association (PPA) offered to partner with GIZ to assist NUC in carrying out an evaluation of its operations in the power sector. The Terms of Reference for the consultancy work provided by PPA is included as Appendix 1 to this report.

In summary, the ToR requires the consultant to:

(a) Assess and evaluate the overall technical operation and management of power systems.
(b) Assess status of all generators and calculate cost of operation in terms of fuel consumption and spare parts required for routine maintenance every 1000hrs and major overhaul after every 30,000hrs.
(c) Assess and make recommendations for Power Station Control systems and Ringmain Feeder Protections.
(d) Assess and make recommendations for Transmission and Distribution protections and possibility of installing high voltage substations in district areas with remote switching controls purposely to reduce high voltage switching lead-time and improve system flexibility for integrating renewable energy.
(e) Determine true cost of electricity and provide a spreadsheet for its updating in the future.
(f) Identify weak and inadequate aspects of the power system and propose actions for bringing them to an acceptable level that will accommodate substantial inputs from renewable energy sources at various locations around the island.

With NUC being an Active Member of PPA, the PPA Secretariat was more than willing to provide the consultancy and hence the Executive Director of PPA, Mr. Andrew Daka, embarked on a mission to Nauru from 6 – 15 February 2013.

In the course of the consultancy the Executive Director had discussions with the following persons.

Table 1: Consultation List

Name	Organization	Designation	Email
Thomas Tafia	NUC	General Manager	ttafia@gmail.com
Hon. Riddell Akua	Republic of Nauru Government	Minister for Transport, Telecommunications, Utilities, Nauru Air Corporation	
Trevor Fry	PPA Energy, EU TA to NUC	Consultant	Trevor.fry@ppaenergy.co.uk
Nickson Toremana	NUC	GM Water and Civil Operations	
Matai Koroi	NUC	Distribution Supervisor	
Andre Adun	NUC	Chief Operations Supervisor	adunandre@yahoo.com
Joel Dapon	NUC	Electrical Supervisor	
Sambruce Akibwib	NUC	Senior Maintenance Supervisor	sambruceakibwib@naurugov.nr
Neil Hughes	MAN Diesel	Manager Primeserv	Neil.Hughes@au.man.eu
Anthony	NUC	Procurement Officer	

2 Management and Governance

NUC was established under the Nauru Utilities Corporation Act passed by the Parliament of the Republic of Nauru in 2011. The Act establishes the Corporation with its objectives of providing "reliable, affordable and sustainable energy, enabling the socio-economic development of Nauru". Under the Act, the CEO of NUC reports directly to the Minister of Infrastructure, Communications and Utilities.

The current organizational structure of NUC is shown in Figure 1 below.

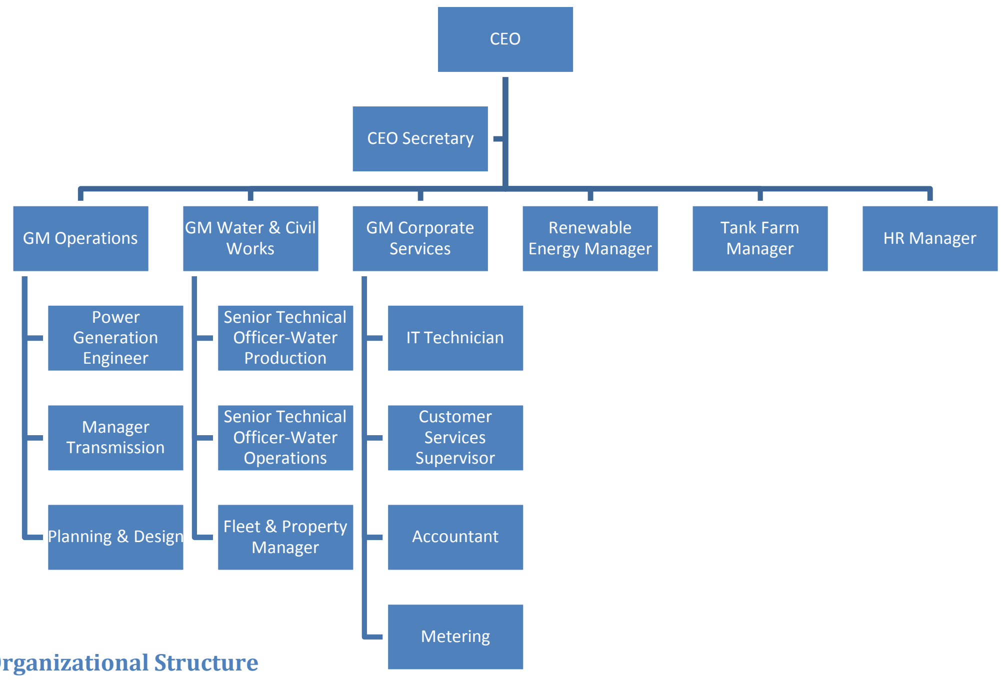

Figure 1: NUC Organizational Structure

Whilst the arrangement may be streamlined, it does not provide a buffer between the management of the operations of the Utility and the utility being used as a political tool. The direction of the utility would be very much exposed to change in governments which could lead to detrimental effects for the people of Nauru.

Whilst NUC presently has an Advisory Committee which is selected by the Minister responsible for NUC, this Committee does not have any decision making powers. Its recommendations to the Minister may or may not be considered.

The appointment of a Board of Directors to which the CEO of the Utilities can report to will create the needed buffer between the Management and the political decision makers which will then clearly demarcate the responsibilities and be in line with good governance principles for utilities.

This lack of governance affects the operations of the utility even as far as the procurement of spare parts where the purchase orders still have to go through vetting by the Government of Nauru (GoN) Finance Department even after approval by the NUC CEO.

Whilst the Nauru Utilities Corporation Act sets up the aims and responsibilities of the Corporation, there are presently no subsidiary legislations/regulations to guide the operations of the Utility. These subsidiary legislations/regulations define the powers of the Corporation in terms of running its daily operations. Without these regulations, the policies that the Corporation develops will have no legal basis in almost all facets of its operations[1].

As an example, at present there are no regulations regarding who can carry out an electrical installation, and who is responsible for what when it comes to wiring of buildings, i.e. there is no demarcation of where NUC and the customers' responsibilities are.

All these items can be easily addressed through the passing of subsidiary legislations or regulations by the Parliament and once passed subsequent changes can be made where needed by the substantive Minister. There are enough examples from the neighboring Pacific Island countries that can be easily adopted to suit Nauru's situation.

The present NUC establishment has a number of crucial positions in power generation and transmission and distribution which are vacant. This has an impact on the performance of the utility. In order to ensure proper functioning of the power operations, the recruitment of the General Manager (GM) Power Operations and the Power Generation Manager must take place as soon as possible.

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[1] Most of the PICs Government owned utilities are established through an Act of Parliament. These Acts have subsidiary legislations or Regulations which provide the basis for their operational functions; e.g. The Solomon Islands Electricity Authority (SIEA) is established through the Electricity Act of 1969. It has subsidiary legislation which sets out how a service is connected, who meets the cost if any, the billing period etc. Nauru has the NUC Act which has been passed. It now needs subsidiary legislations/regulations to govern its everyday operations.

3 Power Generation

Nauru Utilities Corporation's generating facilities comprise a Power Station dating back to the early 1950's with medium speed diesel generators ranging in age from 10 to 37 years old. Table 1 below provides information on the generators.

Table 2: Summary of NUC Generators

Generator Type	Rating (MW)	Speed (RPM)	Year Installed	Running Hours	De-rated Capacity (MW)
#1 Ruston 12RK270 MK1	2.6	750	1989	29,841	1.0
#4 Cummins DTA5	1	1,500	2008	6,650	0.35
#5 Ruston 16RK3C	2.0	750	1976	19,629	Out of Service
#6 Ruston 16RK3C	2.0	750	1977	22,102	1.6
#7 Ruston 12RK270 MK2	2.8	750	2008	22,633	1.2
Total	10.4				4.15

Based on the information in Table 1, NUC's present generation capacity of 4.15 MW does not satisfy either n-1 or n-2 firm capacity. As such, the failure of any one of the generators would result in load shedding. In other words, NUC does not have sufficient capacity to be able to supply the demand in the event of a forced shutdown or indeed to carry out planned or scheduled generator maintenance.

As a consequence of this, planned 10,000 hours maintenances have been put on hold whilst looking at options to commission additional generating capacity, which will be discussed later in the report. Scheduled 30,000 hour overhauls for the three (3) operational Ruston engines are shortly due.

Figure 2: Generator Maintenance Schedule

The only scheduled maintenances that NUC personnel have been able to undertake have been 1,000 hour services. This can be attributed to the non-availability of spare parts to carry out the services.

3.1 #1 Ruston RK270MK1

This generator set was installed in 1989 and at present has 29,841 running hours on it. At the time of the mission the set was operating at 1 MW which is well below the optimum operating condition.


Figure 3: #1 Ruston RK270 Mark 1

The engine is 189 hours short of its 30,000 hour overhaul and has been de-rated due to problems with recent peak pressure readings indicating that there is wear inside the cylinders which with the number of hours on the engine is to be expected. This engine should be overhauled as soon as possible.

The on engine fuel system has several leaks and some of the piping requires replacing. The engine has been hard to start in the past due to bad air start piping, the piping requires replacing. The turbocharger outlet bend and the exhaust bellows both require replacing. The exhaust silencer outside of the station is showing signs of corrosion and should be changed to enable continued reliable operation.

The estimated cost of the major overhaul is AUD 250,000 and AUD200,000 for parts and labor respectively[2]. Any major overhaul would take between 4– 6 weeks to complete depending on how it is arranged with a lead time of at least 8 weeks to procure and ship parts to Nauru.

3.2 #4 Cummins DTAS

This is one of two containerized units which is located outside the powerhouse and is the remaining set from a number of rentals sets that were brought to Nauru in 2003 to address the then shortage of generating capacity.


Figure 4: Cummins DTA5 Unit

Following AusAID funding which resulted in the rehabilitation of the base-load generating sets, two of the rental units were eventually purchased by NUC to provide additional generation capacity during peak periods. The second unit is no longer operational and has been cannibalized for spares to ensure one unit is operational.

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2 NUC does not have the expertise to undertake either a top overhaul or a major overhaul. It has to bring in experts under a contract and hence all labor costs are contract costs.

The generator whilst rated at 1 MW is presently operated at 350 kW which is way below the optimum operating load of seventy to eighty (70 - 80) percent. Like all the Rustons, this set has not undergone any scheduled maintenance.

Extended running of any of the generator units at low loads would result in low fuel efficiency and accelerated engine wear.

3.3 #5 Ruston 8RK3C

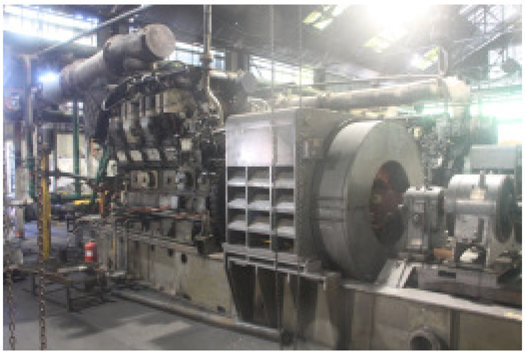

Figure 5: #5 Ruston 8RK3C

This set has been out of service since June 2012 with a faulty 1 MW alternator. It had 19,629 running hours on it when it went out of service. An attempt has been made by the previous Power Operations Manager to hook up a 2 MW alternator to the engine.

This action is ill advised, as the engine is likely to suffer mechanical damage due to the alternator being oversized.

The damaged stator of this alternator is presently sitting out in the open to the salty environment and to return this set to service would require fully stripping the stator coils and rewinding. Work will be also required to repair the old rotor to ensure that it is in serviceable condition. This can be only done overseas and most likely in Australia.

Currently the engine is not connected to the diesel fuel supply as it is believed that the previous supervisors had been attempting to connect this engine to a Hydrogen generator.

The on engine fuel system has several leaks and some of the piping requires replacing.

Best estimates put the cost of repairing the alternator at AUD250,000 with the rotor having to be shipped overseas and the work taking at least six to eight weeks to complete.

The estimated cost of the major overhaul is AUD 450,000 for parts and labor and overhaul taking 4 –6 weeks and a lead time of about 8 weeks as is the case for the #1 Ruston.

3.4 #6 Ruston RK3C

This generating set with a nameplate rating of 2MW is operational but de-rated to 1.6 MW. This engine is has 22,102 running hours and will soon need to undergo its 30,000 hours major overhaul.

Figure 6: #6 Ruston RK3C

Whilst this generator is operational, it was observed during the mission that this set needs urgent attention to address oil leaks that were very evident. The engine on fuel system also has several leaks and some of the piping requires replacing.

Recent peak pressure readings are indicating that there is wear inside the cylinders which with the number of hours on the engine is to be expected and this engine will require a major overhaul before the end of this year depending on the number of hours that it is required to operate.

The charge air system is leaking and requires new rubber sections to be fitted. The engine has been hard to start in the past. Some of this is likely to be caused by bad cylinder compression along with some faults with the air start distributor.

The exhaust system and bellows both require work carried out on them and possibly replacement of some of the components including the silencer.

Using information available, the best estimate for the cost of the major overhaul is AUD450,000 to cover parts and labor with the overhaul taking about 4 – 6 weeks to complete if spare liners and heads are purchased or 6 – 8 weeks if the existing liners and heads are to be reused.

3.5 #7 Ruston RK270MK1

This unit with a nameplate rating of 2.8 MW was installed in 2008[3]. It is currently operational but is heavily de-rated to a 1 MW output. The set has 22,533 running hours and will shortly require a major overhaul.

This set is generally in better condition appearance wise but recent peak pressure readings are indicating that there is wear inside the cylinders which with the amount of hours on the engine is to be expected.

[3] It should be noted here that NUC has had a number of same make and model engines over the past years and with the records not showing serial numbers, it can be difficult to verify when old units were taken off-line and when new ones where installed.

Figure 7: #7 Ruston RK270 Mark II

The on engine fuel system has several leaks with the leaks from the fuel injection pumps that were not properly serviced appearing to be the major source of the fuel leaking.

Anecdotal evidence is that this engine has been unable to run at its most optimal load range of 75 - 80% load since the date of commissioning due mainly to the fact Nauru Utilities did not purchase the correct exhaust silencer for financial reasons and therefore the silencer that had been fitted to the caterpillar engine that was in the #7 position previously was used. Readings taken at the time found that the backpressure on the turbocharger was well outside the recommended levels and the silencer was found to be too small for the application.

The turbocharger outlet bend requires replacing along with the bellows and the silencer.

The charge air inlet pipe had suffering some cracking; this pipe was manufactured on the island from the original material that was installed on the engine at its former power station. The original installation of the engine was supposed to have the charge air pipe come straight out of the engine but the pipe had to bent to allow access for the forklift in front of the engine and as a result of the bends the charge air piping is cracking due to vibration caused by not properly supporting the pipes.

The cost of the major overhaul and associated pipe works to address the charge air issues could easily reach AUD550,000 and like generator #6 taking 3-4 weeks or 6-8 weeks depending on logistics for the overhaul.

3.6 Generator Efficiencies

A good measure of the efficiency of the operating generators is the Specific Fuel Consumption (SFC) of the engine. This measure looks at the number of units (kWh) generated for each litre of fuel used. To be able to accurately measure this important indicator, good accurate data is vital. .

This is a challenge at NUC due to operational data not being frequently collated into a useful format. Whilst raw data is available, it is not readily available in such a way that it Executive Management can use it in a meaningful manner. Furthermore, where the raw data is available, there are cases where data gaps exist due a lack of effort on the part of operators to fill the logbooks.

Furthermore when looking at the fuel consumption for the generators it was noted that there was significant difference between the fuel transferred from the Tank Farm and that used by the engines as taken from the engine fuel meters. There is in fact a higher fuel consumption recorded at the engine fuel meters than that transferred from the Tank Farm as shown in the table below.

Month	Tank Farm Transfer (Litres)[4]	Engine Fuel Meter Readings (Litres)[5]	Difference (Litres) (Tank Farm – Engine)
July 2012	490,952	604,252	(113,300)
August 2012	400,359	589,927	(189,568)
September 2012	436,960	516,927	(79,967)
October 2012	427,778	698,533	(270,755)
November 2012	427,565	581,685	(154,120)
December 2012	523,051	579,030	(55,979)

The problem can be caused by either faulty fuel meters or more likely error in fuel meter readings. At present the fuel usage at the power station is not reconciled with that transferred from the Tank Farm so that the problems causing the difference in the fuel consumption can be determined and addressed. In normal circumstances and based on information provided by NUC one would expect the total engine usage to be less than that transferred to the power station considering other usage such as fuel used by the NUC vehicles and Menen Hotel.

For this report, NUC does not have a complete set of data for a 12 month period and hence the data used to calculate the SFC for the engines had to be extracted from the power station daily log sheets for the six month period 1 July – 31 December 2012. However, there is some uncertainty in the accuracy of the data as there have been periods when there were no generation outputs recorded or fuel readings taken due to no logsheets being available, faulty fuel or kWh meters or other miscellaneous reasons.

Using the six months period, the overall specific consumption of the NUC generation was calculated to be 3.26 kilowatt-hours per litre (kWh/l). The table below also compares the engine fuel efficiencies with those obtained in 2003.

Generator #	Units Generated (kWh)	Fuel Consumption (Litres)	2003 SFC (kWh/l)	2012 SFC (kWh/l)
#1 Ruston RK270 MK1	3,110,100	848,147	4.32	2.94
#5 Ruston RK3C	Unserviceable		3.64	
#6 Ruston RK3C	2,220,600	687,682	2.96	3.52
#7 Ruston RK 270 MK2	5,643,900	1,498,970	Not Available	2.71
#4 Cummins DTA5	726,100	553,088	1.49	1.19
Overall	11,700,700	3,587,887	Not Available	3.26

4 Figures taken from the "Draft 6 – Monthly Financial Report for July – December 2012".

5 Figures taken form Daily power station logsheets for same period

The table shows that with the exception of the #6 generating set, all others are operating inefficiently and work needs to be done immediately to address the problem.

3.7 System Reliability

This section of the report discusses the generation system reliability based on the outage rates and fault reporting.

In the course of the data collection, a request was made to the Chief Operations Supervisor for fault reports. NUC operation staff do not fill any fault reports which can be analyzed. Whilst these faults are noted in the daily logsheets when they do take place, there is no weekly or monthly report or follow up analysis of the faults to address the cause of the faults.

As there is no summary analysis of the fault reports, a sample of the 11 kV feeder faults for January 2013 was examined to get an indication of the number of faults, types and causes of the faults. In examining the fault reports, the following observations were made:

Total number of outages	23
Average Outage Duration	372 minutes[6]
Planned Outages	3
Distribution Outages	8
Mechanical Outages	12

In further examining the impacts of the cause of the outages, it was noted that a significant number of the line faults had resulted in entire feeder outages and in some cases even resulting in blackouts where the feeder protection cannot clear the faults.

Based on anecdotal information, the protection relays setting for the feeders were set when the system loads were much higher than what it is now. A review of the protection settings for both feeder and generator relays could be in order.

3.8 Power Generation Associated Assets

In 2008 GHD, on behalf of AusAID, carried out a review of Nauru's power station assets. The review discussed the status of the generating sets and associated assets covering the fuel oil system, cooling system, starting air system, lubricating oil system, electrical balance of plant and generator hall and structures.

The earlier section of this report has discussed the present state of the generating sets, which in general can be described as needing urgent attention.

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[6] It is worth nothing that a number of the outages recorded were for almost 12 hours. There are instances where the faults occurred at night and were not rectified until the next day.

With little or no maintenance undertaken on any of the associated assets since the GHD review was made, the conditions of the associated assets have deteriorated further in the years since.

Visual inspection of the assets showed heavy corrosion of the pipe works for the fuel, cooling, starting air and lubricating oil systems. Engine cooling radiators also show signs of corrosion and clogging of radiator vanes.

The cable tunnel running under the electrical switch rooms has chunks of concrete falling off the walls and ceiling and is subject to flooding during heavy rain. This poses a risk to staff and equipment and could result in the shutdown of operations.

The NUC power station switchboards consists of some very old ones that are no longer used such as generator panels, motor control panels and other auxiliary equipment panels used in the previous Nauru Phosphate Corporation (NPC) operations.

Generators #1, #5, #6 and #7 generating electricity at 3.3 kV are connected to the power station 3.3 kV busbar. Two 3.3 kV feeder supply the former NPC phosphate processing plants, now operated by Ronphos and the residential area of Field.

The 3.3 kV is then stepped up to 11 kV whereby three (3) 11 kV feeders; two overhead and one underground; supply the rest of the customers and the Government of Nauru administrative center of Yaren.

3.9 Additional Generation Capacity

In recognizing the need for additional generating capacity at NUC to meet the demand and especially to be able to take generators off-line for scheduled maintenance, NUC through funding from AusAID had purchased two used diesel generators to be installed at the power station. The two used diesel generator sets are a Ruston and a Caterpillar.


Figure 8: Recently bought Ruston Unit

Based on information obtained from MAN Diesel, the Ruston unit was first installed in a mine in Australia in 1973 before being bought by Anguilla Electricity in the Caribbean and eventually finding its way to Nauru. This has been moved into the generator bay and currently partially stripped with the alternator yet to be mounted. The engine is missing essential parts such as the radiators and piping for fuel, oil and water.

At the time of the mission, NUC had invited personnel from MAN Diesel to assess the engine and determine the work required to put the engine into service. In my discussions with the MAN Diesel officer, it would take a complete rebuild of the engine before it can be put back in service. Furthermore, the alternator needs to have the windings checked and stripped, rewound if found to be faulty to ensure that there are no future problems with it. It must be noted that the alternator is presently sitting in the open without covers or heating.

Figure 9: 'New' Caterpillar Unit

The second unit is a high speed Caterpillar unit which had been previously used as a standby set for one of the Australian Federal Government offices. This unit is located outside the powerhouse waiting for the completion of the generator shed before it is moved into position in the generator shed.

Like the Ruston, it is missing some major components such as the exhaust stack, the ancillary panels and switchboard.

In addition to the mechanical installation, new low voltage cables need to be run from the unit to the power station switchboard so that the set can be run in parallel with existing units.

3.10 Cost of Overhauls

In collating the costs for the different types of services required for the NUC Ruston engines, enquiries were made to MAN Diesel as well as Pacific Power Engineering (PPE) who has worked on overhauls of Ruston engines within the Pacific region. Additional information was sought from the Fiji Electricity Authority who own and operated a number of engines, which are the same as some of the NUC engines.

From the enquiries it was noted that it was difficult for the suppliers to determine an exact cost without knowing the condition of the engines. As such, both MAN Diesel and PPE were not able to provide spare parts cost.

Based on the costs provided by FEA, the parts required for a 12,000-hour top overhaul and a 30,000-hour major overhaul would be about AUD100,000 and AUD250,000 respectively. The labour costs if the engines are serviced by contractors would range from about AUD 37,000 to AUD 46,000 for a 1,000 hours service up to AUD225,000 for a major overhaul.

Type of Service	Parts Cost (AUD)	Labor Charges (AUD)
1,000 Hours		37,000 – 46,000
12,000 Hours	100,000	97,500 – 122,000
32,000 Hours	250,000	195,000 – 225,000

However, if the overhaul is done using parts exchange with the engine parts supplier or a spare set of cylinder liners were purchased for the engines, the labor costs can be drastically reduced due to the reduction in the number of days required for the overhaul.

3.11 Maintenance Constraints

At present, personnel from NUC carry out all maintenance. Since the departure of the previous Power Operations Manager and the failure of the selected replacement to take up the position, there is concern in the competency of the staff to undertake the overhauls. The planning and technical expertise required in this critical operation of NUC needs to be immediately addressed and so it is welcoming to see that the position is now being re-advertised.

NUC does not carry significant spare parts inventory to enable it undertake either the 12,000 or 24,000 hours overhauls. Its maintenance program is restricted to just the 1,000 hour services as evident from the reports provided by NUC's Assistant Generations Supervisor.

The current maintenance program is constrained by the lack of funds to purchase the spare parts or engage contractors as well as irregular shipping to Nauru.

4 Transmission/Distribution

The NUC customers are supplied through three (3) 11 kV radial feeders; Ringmain North, Ringmain South and Ringmain East; with inter-tie points and two (2) 3.3 kV feeders.

The Ringmain North and Ringmain South feeders are of overhead construction consisting of steel poles and cross-arms. The conductors are primarily bare copper conductors of unknown size; however, the Distribution Supervisor advised that it is very likely that the conductor is 7/.064 which is 16 mm2 in the metric system.

The Ringmain East feeder, which supplies the International Airport and the Government offices, is a three core 70 mm2, aluminum cable as advised by the Distribution Supervisor. This feeder runs in parallel with the Ringmain East between the Airport and Menen Hotel.

The overhead transmission/distribution network has deteriorated badly particularly on the Ringmain North feeder, which is on the windward side of the island. There is heavy corrosion affecting all the poles, transformer, line fittings and conductors

It was noted during inspection of the feeders that most of the distribution line fuses were no longer functioning. This has resulted in non-discrimination of faults and in quite a high number of cases resulting in blackouts in the system.

On the positive side, NUC has recently commenced a program of replacing the steel poles with wooden ones as well as the replacement of faulty line fuses to reduce the extended outages. A number of distribution transformers need to be replaced immediately as oil is leaking badly from the tanks.

At present there is a €1.3 million technical assistance and equipment grant from the European Union (EU) EDF10 to assist NUC to purchase urgently needed distribution line hardware, conductors, poles and transformers. This EDF10 funding will also look at replacing and upgrading the conductors to cater for future load growth and any renewable energy generation that is connect to the grid.

It should be noted that a significant portion of the feeder outages are caused by failure of distribution line items and as such the work done using the EU EDF10 funding should reduce the number of feeder outages or restrict outages to smaller sections of the network.

5 Finance

At the time of the mission, no audited financial reports were provided although a draft 6 Monthly Financial Report for July – December 2012 was made available. This is a variance report for the period comparing budget estimates and the actual expenditure.

In addition, copy of the Budget Submission for Financial Year 2012/2013 was provided which was submitted to the GoN for approval on 26 June 2012.

Both documents list Income and Expenditures under the following headings/cost centres.

Income		Expenditure	
Head	**Description**	**Head**	**Description**
4-1000	Electricity Income	6-0000	General & Administrative Expenses
4-2000	Water Sales	6-5100	Employment Expenses
4-3000	Fuel Sales	6-5400	Contract Workers Expenses
4-5000	Rental	6-6000	Occupancy Costs
4-6000	Miscellaneous Income	6-7000	Repairs and Maintenance
4-7000	Tank Farm Income	6-9010	Duty and Taxes
4-8000	Other Income	9-0000	Other Expenses (AusAID Projects)

The draft financial statement for the six month period (July – December 2012) shows an net operating profit of AUD4,278,025.35 taking into account the project funds , subsidy and associated project expenses[7].

However, the financial statement does not show the cost of fuel used in power generation for the six-month period as it is the Government of Nauru (GoN) and not NUC which pays for the fuel. This is the most significant cost item for any electric utility that generates electricity using diesel fuel and needs to be reflected in the financial accounts even if it is subsidized. Otherwise the financial statement of the utility does not reflect the real cost of producing electricity.

It is standard practice with utilities that its accounts are set up such that costs are charged to the different departments of the entity, which are defined by the different functions such as Board & Management, Administration, Generation, Transmission & Distribution and Revenue Collections etc. This is not the case for NUC and hence it is not easy to determine the contribution of each function of the utility to the cost of electricity. To do this would entail going through all the accounts and picking out which costs should be attributed to which department.

Even more difficultly would be encountered if trying to determine the cost of generating electricity for each of the generating units as required under the ToR for this study. In fact,

[7] NUC 6 Monthly Financial Report for July – December 2012. Reference to accompanying notes 17 – 22.

the cost for each generator unit producing electricity cannot be calculated with the way the accounts are presented unless the accounting system is changed such that all costs (spare parts, labor, etc) expended on operating and maintaining that unit is charged to that unit and not all lumped together.

5.1 Cost of Generation

In attempting to determine of cost of generating, every effort has been made to include the relevant costs from NUC's financial accounts affecting the cost of generating electricity.

Using costs obtained from the Draft Financial Report for July – December 2012 and the fuel consumption obtained from the power station logsheets for the same period; the cost of supplying electricity to the customer, however, is calculated to be AUD0.46 [8]per kilowatt-hour.

5.2 Electricity Sales for July – December 2012

The NUC average system load is 2.86 MW giving an average total monthly generation of 2,052,000 kWh or 12,312,312,000 kWh for the six-month period. The total number of units exported to the grid after accounting for power station auxiliaries was 12,788,400 kWh as taken from the power station logsheets.

However, based on the Draft Financial Report for July – December 2012, the total units sold for the period was 2,775,690 kWh. This is a difference of some 10,000,000 units or roughly 80% of exported units. These units need to be accounted for as this is a figure too big to attribute to system losses.

[8] The total of the Power Operations Cost divided by the total number of electricity units (kWh) generated. It is difficult to determine the actual generation costs with the accounts as they are.

6 Analysis of Data

The purpose of this section of the report is to look at the present situation at NUC and put forward options for getting NUC to operate efficiently again. It will also look at the cost options for overhauling the NUC generators and getting them to a high operational efficiency.

6.1 Generator maintenance

Under normal circumstances, where the generators are well maintained, the installed capacity of 10.4 MW would be adequate to meet the n-1 or n-2 criteria for firm capacity. However, with the generating sets greatly de-rated, the total generating capacity is now 4.14 MW which barely meets the demand and satisfies neither of the firm capacity criteria.

At the time of the visit, electricity supply to the customers was derived from three of the four NUC Rustons as well as the Cummins containerized unit. The fourth Ruston unit has been out of service since May 2012. NUC with funding from AusAID had also purchased two used units; a Ruston and a Caterpillar; both of which require substantial work before they can be commissioned.

Generator No.	Rating (MW)	Speed (RPM)	Year Installed	Running Hours	De-rated Capacity (MW)
#1 Ruston 12RK270 MK1	2.6	750	1989	29,841	1.0
#5 Ruston 16RK3C	2.0	750	1976	19,629	Out of Service
#6 Ruston 16RK3C	2.0	750	1977	22,102	1.6
#7 Ruston 12RK270 MK2	2.8	750	2008	22,633	1.2
#4 Cummins DTA5	1	1,500	2008	6,650	0.35

The urgency for NUC now is to overhaul the operational units to get the additional generating capacity as well as improve the fuel efficiency of the generators. This is a challenge for NUC due to limited finances, the lack of spare parts inventory and the lack of skilled personnel to carry out the required scheduled services.

Almost as important is the effect on the customer of taking these units offline, as it would inevitably result in load shedding for the duration of the maintenance program (which could be up to two months). However, this duration can be reduced significantly if an arrangement is in place to use exchange parts or the purchase of a spare set of critical parts that can be swapped, for example cylinder liners, to reduce down time.

Having this arrangement in place not only reduces downtime but also the cost of the overhaul due to the reduced man-hours required.

The cost of the overhauls based on best estimates could be up to AUD500,000 for a major and up to AUD350,000 for a top overhaul.

The absence of a spare parts inventory is worrying as the likelihood of repairing a breakdown of any significance would be non-existent. Any such breakdown would result in extended load shedding until the necessary parts are sourced and freighted to Nauru. This could take up to two to three months?

6.2 Fuel usage

An important matter to consider is the reconciliation of the fuel usage for electricity generation. We have noted in the previous section of the report the significant differences in the fuel used between that transferred by the Tank Farm and that used by the generators as recorded in the logsheets.

6.3 Distribution Network

For the transmission/distribution network, the initial work of replacing poles, transformers and line hardware will result in reduced number of outages and limiting outages to the faulty section of the network.

However, work needs to continue on the pole and equipment replacement on the 11 kV feeders especially on the Ringmain North feeder.

Furthermore and whilst upgrading work is done on the feeders, attention needs to be also made to the grading of line protection fuses. This work can be done as part of an overall protection coordination study also looking at the feeder and generator protection settings.

6.4 Electricity Sales

Unlike most other businesses, utilities have only one commodity (electricity) to sell to its customers. Hence, the number of units of electricity sold is critical to the health of the utility. The utility always aims to sell as much of the electricity units generated as possible after taking into consideration its power station auxiliary usage and reasonable level of system losses, both technical and non-technical.

This is a concern to NUC based on the information available as there is a very big difference between the total number of units sent into the grid and the total number of units sold. The total number of units sold for the six months, July to December 2012, is only 22% of the net electricity sent into the grid.

6.5 Data Management

The availability of reliable data is important to assessing the performance of the utility. This is an important area that NUC must prioritise. Whilst raw data is available, it needs to be organized in such a way that it is useful to the Management Team. More often than not, this is a task that the supervisors can take on in the normal course of their duties by providing regular summary reports covering the important data.

Where the data can be obtained from more than one different source, the data needs to be checked to ensure that they do agree with each other. For example, the volume of fuel transferred from the Tank Farm must be equal to the fuel used by the generators for electricity generation plus what is used by the vehicles and other purposes.

7 Conclusions and Recommendations

The following section of the report outlines and recommends the actions required by NUC to address the issues raised in this report. The recommendations are to address the immediate problems of the lack of generating capacity, impending major overhauls of the generating sets as well as the replacement of poles and line hardware and the high outage rates.

7.1 Generation

Based on the assessment and evaluation carried out, the following actions need to be implemented to improve the performance of the engines as well as information for decision-making.

- Engaged a contractor to carryout overhaul of all the Ruston generators to recover lost generating capacity and improve fuel efficiency
- Procure spare parts to carryout scheduled service on the Cummins unit to recover generating capacity and improve fuel efficiency
- Draw up overhauls schedule for all generating sets to ensure minimum outage duration during the overhaul period
- Engage a consultant to carry out a protection coordination study to review the protection settings on the generator, transformer and feeder relay settings
- Draw up and implement reporting processes to cover generation statistics, fuel reconciliation and other critical process.
- Engage a consultant/contractor to draw up a ToR for the installation of the two used AusAID purchased generators
- Recruitment of the Power Operations Manager to oversee the operations of the Power Generation Section
- Consider the construction of a new power station in the medium to long term plans

7.2 Transmission and Distribution

For the Transmission and Distribution function, what is required is to continue the program of replacing the aged and faulty equipment. The European Union EDF10 funding should see acceleration in the maintenance program resulting in reduced number of outages. However, the following actions are also required:

- Schedule maintenance program for replacement of all aged and faulty equipment
- Engage contractor to replace 11 kV cubicle and switchgear on Ringmain East feeder along the Airport road. Work will include termination of cables.
- With dropout fuses replaced, appropriately grade fuses for better discrimination of faults
- Commence on basic lineman training in-house utilizing the present Distribution Supervisor's expertise in lineman training

7.3 Finance

In order to better allocate costs and assist in the Management Team's understanding of its cost of operations the following action are recommended.

- Revise the NUC Chart of Accounts to enable costs to be charged to departments defined by the different responsibilities
- Revise the Power Generation cost codes so that labour and materials can be charged to individual generators to be able to determine the cost of producing electricity by individual unit
- The need to take up the cost of fuel used to generate electricity into the NUC accounts to truly reflect the cost of generating electricity and hence the financial situation
- Carryout investigation into the huge difference between the electricity units generated and those sold
- Charge the electricity usage by the Water Section and Tank Farm to the relevant Sections cost of operations

7.4 Governance

The following recommendations are made to ensure that there is a clear demarcation of the roles and responsibilities of the stakeholders of NUC. This would improve the efficiency of NUC by avoiding micromanagement and duplication of roles and ensuring clear guidelines for the Management Team at NUC as well as facilitating dialogue between stakeholders.

- Creation of a NUC Board of Directors to oversee the operation of the utility in ensuring the goals and objectives set out by the GON is achieved
- Draw up relevant technical guidelines and subsidiary legislations outlining the procedures for NUC in dealing with aspects of the utility operations such as connections, charges and the responsibilities of customers and NUC in terms of the provision of services.

Appendix 1. SPC/GIZ CCCPIR TERMS OF REFERENCE
Technical Evaluation and Assessment Study of NUC Power Generation and Distribution Systems
(Revised)

1. Context

The SPC/GIZ CCCPIR regional programme aims at strengthening capacities of Pacific Island Countries and regional organisations to adapt to and mitigate the impacts of climate change. CCCPIR will achieve this objective through working in 6 thematic components, namely 1) strengthening the regional advisory and management capacity; 2) mainstreaming climate considerations and adaptation strategies; 3) implementing adaptation and mitigation measures; 4) sustainable tourism and climate change; 5) sustainable energy management; and climate change education.
The programme covers 12 Pacific Island Countries (PICs) and has its main office in Suva. The sustainable energy management component is being implemented from 2012 to 2014 in six countries, namely Fiji, Kiribati, Nauru, Tonga, Tuvalu and Vanuatu. In Nauru the main activity supported by the CCCPIR programme is the development of an energy road map, including an action plan for the power sector.

2. Background

The existing power generation and transmission equipment were installed during BBC (British Phosphate Company) and Nauru Phosphate Commission which is approximately over 50 years old. There have been changes made to some of the equipments but the fundamental system has never been changed and is one of the oldest systems exists in the region.

The power station is currently facilitated with the following types of generator sets:

Generator Type	Capacity (Megawatts)	Current Status
Generator No. 1Ruston RK270MK1	Rated: 2.6 Megawatts	Currently Operating on 1.3Megawatt.
Generator No. 6 Ruston RK3C	Rated: 2.0 Megawatts	Currently operating on1.6Mega watts.
Generator No.7 RK 270 MK2	Rated: 2.8 Megawatts	Currently operating on 1.5 Megawatts.
Generator No.4 Cummins	Rated: 1Megawatts	Operating on 450Kilowatts and is currently used to power Anabar District.

The power generation system was designed to control by a main control switchboard with a 3.3kv bus-bar.
Electricity supply is transmitted around the island at 11,000 and 3,000 volts and distributed at 415/240 volts 50hz.

As a result of numerous technical issues in both power generation and transmission systems, management has therefore decided to carry out a technical assessment and evaluation study of the existing power generation and transmission systems. This will enable NUC to develop strategies and undertake short, medium and long actions in order to resolve problems and improve its service deliveries to the public.

3. Scope of Works

(a) Access and evaluate the overall technical operation and management of power systems.
(b) Assess status of all generators and calculate cost of operation in terms of fuel consumption and spare parts required for routine maintenance every 1000hrs and major overhaul after every 30,000hrs.
(c) Assess and make recommendations for Power Station Control systems and Ringmain Feeder Protections.
(d) Assess and make recommendations for Transmission and Distribution protections and possibility of installing high voltage substations in district areas with remote switching controls purposely to reduce high voltage switching lead time and improve system flexibility for integrating renewable energy.
(e) Determine true cost of electricity and provide a spreadsheet for its updating in the future.
(f) Identify weak and inadequate aspects of the power system and propose actions for bringing them to an acceptable level that will accommodate substantial inputs from renewable energy sources at various locations around the island.

4. Outputs

Within 4-6 weeks period, the Consultant is expected to prepare and submit a complete report covering the following:

a. the overall technical evaluation of all power operations and management systems and make recommendations on possible strategies and actions for needed improvements.
b. assessment of power transmission and distribution equipment and provide recommendations on strategies to address technical issues and application of appropriate technologies to improve control switching and system protections.
c. assessment of each generator and discuss impact on current operational costs (maintenance needs, fuel efficiency, station energy component for that generator, lube oil use etc), financial and economic viability, reliability and sustainability of equipment and confirm the true cost of energy generated by that unit.
d. recommendations and strategies for short, medium and long term investment plans.

5. Timeframe, location and reporting

The work is expected to start by a mission to Nauru from 6th to 15 February and then be completed by end of March from Suva, Fiji.
An indicative timetable for Lavaneta the deliverables of the work is as follows:

Item	Indicative deadline
Mission to Nauru	6-15th February
Draft Report	8th March 2013
Final Report	31st March 2013

Reports should be submitted in electronic copy (Word and PDF) to NUC and GIZ.

Comments on the draft report will be provided by NUC and GIZ within 10 days of receipt.