Nauru Energy Sector Overview

October 2013

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Acknowledgements and data collection

This report was prepared by Dr. Herb Wade (IRENA and GIZ Energy Road Map Consultant) and Katerina Syngellakis (SPC-GIZ Sustainable Energy Management Adviser) with inputs from Apisake Soakai (IRENA Pacific Coordinator) on the request of the Government of Nauru.

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The authors would also like to thank the Pacific Power Association and the Pacific Regional Infrastructure Programme (through the Pacific Investment Advisory Centre) for their assistance during the preparation of this report.

Acronyms

ADO .... Automotive Diesel Oil
ADB .... Asian Development Bank
AOSIS .... Alliance of Small Island States
AUD .... Australian Dollars (currency)
CIE .... Department of Commerce, Industry and Environment
EEZ .... Exclusive Economic Zone
EU .... European Union
GEF .... Global Environment Facility
GHG .... Greenhouse gas
GIZ .... Deutsche Gesellschaft für Internationale Zusammenarbeit
GoN .... Government of Nauru
IRENA .... International Renewable Energy Agency
JICA .... Japanese International Cooperation Agency
km^2 .... Square kilometres
kV .... Kilo Volt (thousands of Volts)
kWh .... Kilowatt hours (thousands of Watt hours)
kWp .... Kilowatts peak (rated output of solar panels)
LED .... Light Emitting Diode
LPG .... Liquid Petroleum Gas
ML .... Megalitres (millions of litres)
MW .... Megawatts (millions of Watts)
MWp .... Megawatt peak (rated output of solar panels)
NASA .... National Aeronautics and Space Administration
NERM .... Nauru Energy Road Map
NUC .... Nauru Utilities Corporation
OTEC .... Ocean Thermal Energy Conversion
PPA .... Pacific Power Association
SIDS .... Small Island Developing States
RPC .... Regional Processing Centre
SPC .... Secretariat of the Pacific Community
TEPCO .... Tokyo Electric Power Corporation
UN .... United Nations
UNFCCC .... United Nations Framework Convention on Climate Change
USD .... United States Dollar

As of 1st October 2013, the exchange rate was AUD 0.93122 per USD (OANDA, 2013)

Executive Summary

The aim of the present report is to provide a stock take of the current situation in the energy sector of Nauru and therefore inform a baseline which can be used in the development of the Nauru Energy Road Map (NERM). As such, this report will present:

- General country context (geography, economy, population, etc.);
- Energy sector landscape covering supply and demand and institutional arrangements;
- Experience, potential and challenges in the use of renewable energy and energy efficiency; and,
- Data needs for the energy road map and beyond.

This report does not include information on the Regional Processing Centre (RPC) as the centre currently caters for its energy requirements largely independently of the rest of the Nauru energy sector.

Petroleum imports

The average amount of petrol purchased by the government for its own use and for distribution is around 1.5 million litres (ML) a year. Automotive diesel oil (ADO) is around 8.8 ML and jet fuel around 1.3 ML. The Government has frequently relied on grant funding from Australia and Japan for the purchase of petroleum imports for the power sector. RONPHOS also do their own purchasing of petroleum products. Liquified petroleum gas (LPG) and kerosene are imported and distributed by the private sector. Diesel fuel and petrol are stored and distributed by Nauru Utilities Corporation (NUC) to all users except RONPHOS who maintains a separate diesel fuel storage facility and often imports diesel for their industrial use. Jet fuel is used only by the national airline Our Airline though the NUC does manage its storage along with that of other petroleum products.

Electricity

Nauru's grid electricity supply comes from a single power station operated by NUC. The generation, transmission and distribution equipment is old, with much of it urgently needing repair or outright replacement. The existing diesel engines have enough capacity to meet demand but if any one engine breaks down, load shedding is necessary. Maximum demand was once in excess of 7 MW but has dropped, largely due to the loss of industrial demand, to around 3.6 MW dominated by domestic usage. The weekday baseload is around 2MW.

Prepayment meters have been installed since 2009 for most domestic and commercial customers. There have been reports of prepayment meter tampering. The tariff is still heavily subsidised, with a residential rate of 0.10 AUD /kWh up to 300 kWh and 0.25 AUD /kWh for additional energy. Commercial customers pay a flat rate of 0.30 AUD /kWh. The industrial (phosphate) rate is 0.50 AUD /kWh and the government is now being charged 0.50 AUD /kWh. Full cost recovery is estimated to be between 0.45 and 0.49 AUD per kWh.

Due to the major structural changes taking place in the Nauru economy in particular the reopening of the Regional Processing Centre (RPC), accuracy is very low for forecasting future energy use.

Energy security

In 2012, SPC released 36 energy security indicators for Nauru. While Nauru ranked high in some indicators such as electrification (100%, compared to a SIS average of 68%) and affordable tariffs (14USc/kWh compared to a SIS average of 36USc/kWh), it had low scores for renewable energy share in the overall energy mix at 0.05% and only an estimated 73 days of fuel supply security. No significant programmes have been put in place to improve demand side energy efficiency.

Institutional, regulatory and legal arrangements

The Nauru Energy Policy Framework (NEPF) was endorsed in 2009 and layout broad aims and strategies for the energy sector, including power, renewable and energy efficiency. The NUC currently provides all electricity services to Nauru except for RPC and the main processing plant of RONPHOS. The status of the utility as a corporation was formalised with the passing of the Nauru Utilities Corporation (NUC) Act 2011 which states the legal obligations of the utility. Under the Act, the CEO of NUC reports directly to the Minister of Utilities. The NUC Act includes a limited number of regulations that deal with recovery of fees from post paid customers and a small number of operational issues however, there is a need for additional subsidiary legislations and regulations to further guide the day-to-day operations of the utility.

In 2012 NUC developed a Corporate Strategy with technical assistance from the Asian Development Bank (ADB) including vision, objectives and performance indicators. Priority areas identified in the strategy include: power generation and distribution systems, research and implementation of renewable energy projects, energy efficiency, improved tank farm management and overarching financial management and control and capacity building.

With regard to the institutional framework for energy policy-making, planning and regulation within government, there have been very limited resources dedicated to the energy sector to date with responsibility for energy being given to the Environment Unit in the Department of Commerce, Industry and Environment (CIE).

Renewable energy

The 2005 National Sustainable Development Strategy (NSDS) and the 2009 Energy Policy Framework both state Nauru's aim to make 50% of energy provided through renewable energy by 2015.

Solar resource measurements show an average of over 6 kWhr/m^2/day with a seasonal variation of around 10-15%. A solar pre-feasibility study has shown that up to 1 MWp of solar PV could be installed without storage. In terms of electricity production, a 30% midday demand penetration represents around a 5% yearly energy penetration for the conditions in Nauru. Wind resource measurements conducted over one year indicate an annual average wind resource of 4.22 m/sec at 30 meters (about 4.7 m/sec if extrapolated to 50 meters) for 2009-2011.

With little or no biomass present at topside, there are currently insufficient biomass resources for either combustion for electricity or significant production of biofuels. There may be scope for some domestic-scale piggery biogas projects for cooking but this requires an assessment of pig stock.

Wave energy in the equatorial region is low with around 10-15 kW/m estimated from satellite observations. Even if wave conversion systems become commercially available, the low resource will make it difficult for Nauru to economically develop wave power. There is an opportunity for OTEC energy development once engineering and commercial trials are completed elsewhere but would be a long-term future development.

Currently approximately 1% of Nauru's electricity is generated from renewable resources with all of this contribution coming from solar PV systems of an estimated total installed capacity of 230 kWp.

Supply Side Energy Efficiency

NUC has a relatively low internal energy use of 2.27%, a somewhat high 4.43% for technical losses and a very high 15.77% non-technical loss which includes unbilled usage. Non-technical losses are primarily financial losses and though their reduction will improve the financial condition of NUC, they have little effect on actual energy production or use though of course in the long term the utility will be unable to maintain a high quality of service if it cannot maintain an adequate financial return.

Losses in un-billed usage, notably streetlights, can be significantly reduced by replacing existing equipment with energy efficient units. NUC's electricity transmission system is old and overall distribution losses could also be reduced by simple replacement of worn out equipment. The EU is currently funding a distribution network rehabilitation project. NUC management would like to see a complete rebuild of the system moving the overhead system to below ground.

A general survey of the existing distribution system should be carried out and, if shown to be economically reasonable, a plan prepared for upgrading and/or changing to an underground system. This would allow better management of energy flows in the distribution system through centralized controls at the power house and reduce basic losses in the system components.

More fuel efficient engines are available and fuel efficiency should be a high priority when replacing existing engines or adding capacity. The NUC generators are aged and in poor condition, as indicated by the high level of de-rating of all the units.

The primary challenge for implementation of supply side energy efficiency measures appears to be access to funds for the needed capital investments and management of contracts to bring in overseas contractors to carry out much of the maintenance, repair and replacement work. In general it is clear that NUC management has a good understanding of how to improve supply side efficiency but does not have access to the funds and human resources needed to carry out the actions. Benefits from supply side energy efficiency should be highlighted where they are cost-effective and put forward for support alongside renewable and demand side energy efficiency.

Demand Side Energy Efficiency

Decades of very low (or no) electricity costs for energy consumers has resulted in a much higher per-capita energy usage than is seen in most island countries. Therefore, there are many opportunities for energy efficiency improvements, particularly in the residential and government sectors. However, until there is a better understanding of the actual energy use patterns and the energy using equipment's characteristics, well targeted programmes to reduce energy consumption cannot be confidently prepared. Surveys and audits should precede the design of programmes for demand side management (DSM).

From 2007 to 2010 various demand-side activities were undertaken in Nauru under the auspices of the REP-5 project, funded by the European Union. These included in

2009 the installation of over 1800 pre-payment meters in homes and businesses. A demand-side energy efficiency action plan was also drafted and two energy efficiency officers were hired. The two officers carried out an awareness campaign on energy efficiency and conservation that targeted homes and small businesses. However, after the end of the project in 2010, the energy efficiency officer contracts were not renewed and the campaigns were not sustained. This shows the kind of long-term continuous measures required for DSM cannot be dependent only on external short-term project funding.

A major driver of demand side energy efficiency is the energy price. So long as energy costs remain artificially low, as has long been the case in Nauru, programmes to improve demand side efficiency will tend to have only a short term effect with energy usage soon rising back to pre-programme levels after the programme concludes. For demand side energy efficiency programmes to have the longest lasting benefit, the energy using hardware needs to be upgraded with low maintenance, long lived, high efficiency equipment and consumers must expect substantial price hikes for energy in the future (e.g. a government plan to reduce subsidies on electricity).

Data collection needs

In order to plan future programmes and projects in Nauru's energy sector and monitor progress toward the goal of providing 50% of Nauru's energy with renewable energy, it is essential that accurate, timely, complete data is collected, stored and managed.

Unambiguous records of the quantity of fuel imports, their timing and the specific type of fuel imported are needed. Fossil fuel usage for land transport, sea transport and air transport should be accurately collected along with the patterns of usage of energy for each type of transport. Fossil fuel use for electricity generation and the pattern of electricity usage are essential data currently lacking. Diurnal electricity load patterns, load patterns on different days of the week are also very important data needed. High-resolution load data are necessary for accurate grid stability modelling.

Data regarding the electricity generation, transport and other services that are provided by renewable energy must also be collected. As new renewable energy projects are installed, the energy they provide and information on the use made of it should be collected.

In order to be able to design renewable energy systems and predict their performance, a good understanding of the renewable energy resource on Nauru is required over long periods of time. There is currently collection of some solar resource data on Nauru. However, the wind resource monitoring equipment has been damaged which may have affected the quality of the data it is collecting. A new wind mast has been installed recently and will be able to provide wind data for analysis in the next year.

In order to be able design effective DSM programmes there is a need for NUC to be able to synthesise monthly energy usage for individual customers and businesses. The necessary software will need to be obtained through the supplier of the prepayment meters. A detailed survey of household and small business energy use will be needed and energy audits of commercial entities, RONPHOS and Government offices.

Since roughly 20% of electrical energy supplied by NUC is used for water desalination, a detailed audit of the entire water system from connection to the grid through end use is required.

1 Introduction

1.1 Nauru Energy Road Map

In order to achieve Nauru's ambitious goal of reducing the country's high reliance on imported fossil fuel by meeting 50% of its energy needs from renewable energy sources by 2015,[1] the Nauru Government requested technical support from GIZ, SPC and IRENA in the development of a Nauru Energy Road Map in early 2012.

In response to the request, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the Secretariat of the Pacific Community (SPC) and the International Renewable Energy Agency (IRENA) agreed to offer a joint ~~technical assistance~~support to the development of the Nauru Energy Road Map.

The first kick-off workshop held in May 2012 confirmed that it is critical to introduce more reliable and sustainable energy in order to reduce high dependency on imported fossil fuel.

The key drivers of the road map were identified as:

- Reduce dependence on fossil fuels;
- Improve planning and coordination (within the energy sector);
- Improve energy efficiency;
- Improve cost-effectiveness of energy services;
- Provide more reliable, sustainable and clean energy; and,
- Attract funding to the energy sector.

It was agreed that the Energy Roadmap should take a "whole-of-sector approach" including both energy efficiency and renewable energy assessments.

In July 2012, GIZ, SPC and IRENA established a Technical Assistance (TA) team to support the development of the Roadmap.

In November 2012, the Nauru Government organized a second national consultation workshop to define the framework of the development of the Energy Roadmap including the vision, approach and methodology and to discuss the key strategies, activities and timelines in various sectors to reduce the dependency on imported fossil fuel.

There was a general consensus that the Energy Roadmap should serve as an implementation plan for the 2009 National Energy Policy Framework (NEPF) and the 2005 (revised 2009) National Sustainable Development Strategy (NSDS). The vision of the NSDS is to provide a reliable, affordable, secure and sustainable energy supply to meet the socio-economic development needs of Nauru.

[1] Part of the goal set in the National Sustainable Development Strategy (NSDS) 2005-2025

1.2 Aims of the report

The aim of the present report is to provide a stocktake of the current situation in the energy sector of Nauru and therefore inform a baseline which can subsequently be used in the development of the Nauru Energy Road Map.

As such, this report will present:

- General country context (geography, economy, population, etc.)
- Energy sector landscape covering supply and demand and institutional arrangements
- Experience, potential and challenges in the use of renewable energy and energy efficiency
- Data needs for the energy road map and beyond

This report does not include information on the Regional Processing Centre (RPC) as the centre currently caters for its energy requirements largely independently of the rest of the Nauru energy sector.

2 Country context

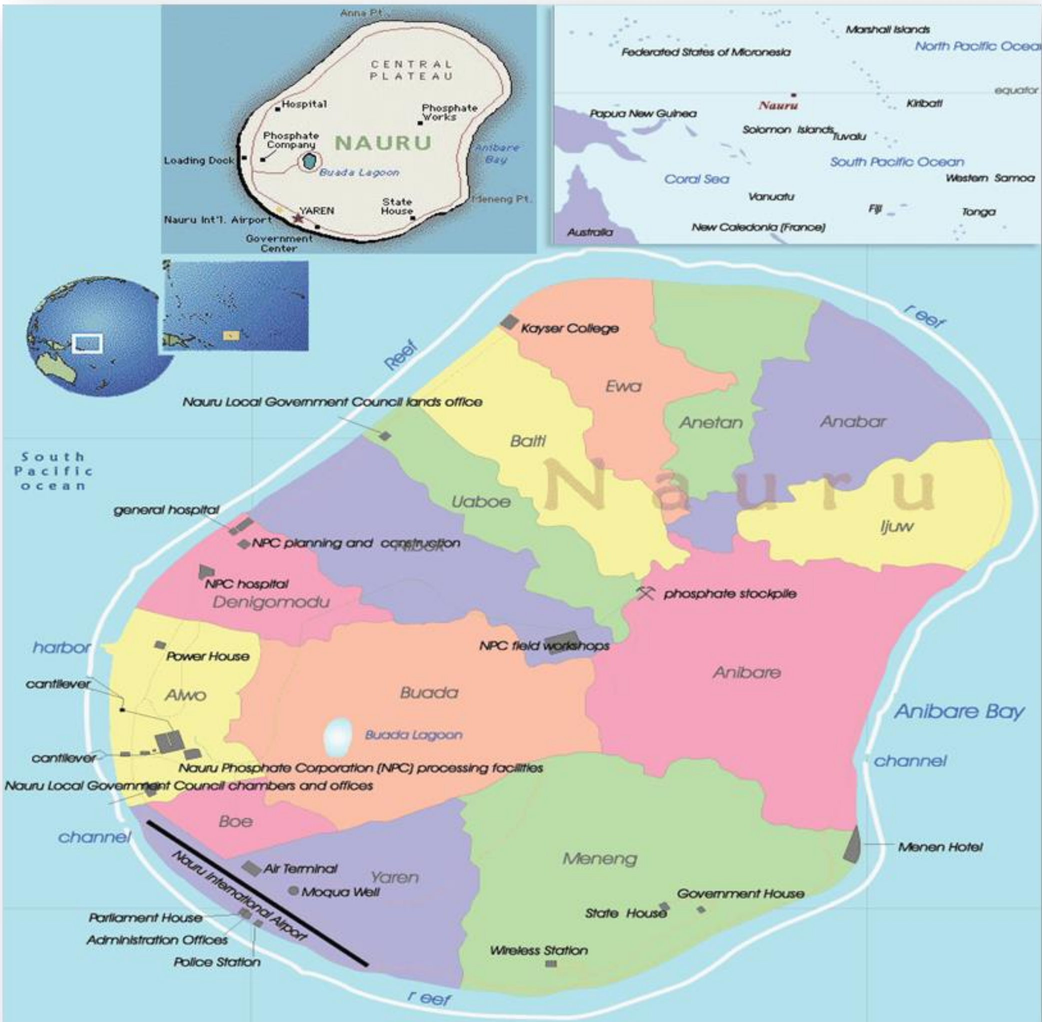

Figure 1 - Map of Nauru and its location

Source: Government of Nauru

2.1 Physical Description

The Republic of Nauru is an isolated, uplifted limestone island located 41 km south of the equator at 0°32' S latitude and 166°56' E longitude (SOPAC, 2007). Its total land area is 21 km^2 with an Exclusive Economic Zone (EEZ) of 320 000 km^2 (PIFS, 2013). Nauru's land area measures 6 km by 4 km, with a circumference of 19 km. Nauru is the smallest independent nation in the world (NBoS, 2007). The island is divided into two separate plateau areas – "bottomside" a few metres above sea level, and "topside" typically 30 metres higher. The topside area is dominated by pinnacles and outcrops of limestone, the result of nearly a century of mining of the high-grade tricalcic phosphate rock. There are no natural harbours and the island is surrounded by a fringing reef 120-400 metres wide. However the reef falls off very rapidly, allowing deep-water ships to moor within a short distance of its edge (PIREP, 2004).

Fresh water is a serious problem on Nauru with potable water coming only from rainwater collection and reverse osmosis desalination plants (PIREP, 2004). Nauru is a permeable island with very little surface runoff and no rivers or reservoirs. Potable water is collected in rainwater tanks from the roofs of domestic and commercial buildings. Water for non-potable uses is obtained from domestic bores at houses around the island (SOPAC, 2007). Shallow groundwater is the major storage for water between rainy seasons. There is increasing salinity in the groundwater bores around the perimeter of the island, and increasing demand for groundwater water due to development. Groundwater is contaminated by wastewater disposal from houses, shops, commercial buildings and RPC (SOPAC, 2007).

2.2 Population

The latest census was undertaken in 2011 and points to continuously growing population for Nauru during the next 40 years. The total population at the time of the census was 10,084 (5,105 males and 4,979 females). This compares with 9,233 people in 2006 – an increase of 9% or 851 people. This population increase represents an average annual growth rate of 1.8%. However, currently the population growth is much higher than 1.8% as Nauru‘s fertility is increasing, and should be around 2.9% which translates into an annual increase of about 300 people per year. The census report predicts that Nauru’s population will increase to between 13-15 thousand people in 2030 and will increase to about 15-21 thousand people in 2050 depending on the level of migration. However, should the population continue to grow at its current level without any significant levels of emigration, the population will be 27 thousand people in 2050. The population will age, with a decreasing proportion of young people aged 15 and younger, and an increase in people aged 60 and older. In 2013 a significant influx of people into Nauru has been noted due to the reopening of the RPC and the related boost economic growth through its impact on construction, hotels and accommodation, restaurants, and retail trade. However, this increase in people arriving into Nauru may not be permanent.

2.3 Environment

The climate is equatorial and marine in nature. There are no cyclones, although rainfall is cyclic and periodic droughts are a serious problem. On average, Nauru experiences a drought period every 5.2 years and each drought has an average length of 19 months. There has been a recorded period of drought that has lasted up to three years (GoN, 2012). Rainfall averages 2080 mm per year but one year recorded only 280 mm of rainfall. The drought from 1998 to 2001 stretched the water resources on the island and resulted in overuse of the lens and a decline in water quality, leading to rising health and environmental issues due to soakage from household sewage pits into the increasingly brackish and contaminated groundwater (PACC, 2006).

Phosphate mining has occurred on Nauru for over a century, with consequent landscape degradation over a wide area and decline in soil quality, rendering over 70% of the land area uninhabitable and almost all of the land non-productive. This loss of soil fertility and reduced crop cover exposes soils to high levels of UV radiation which further reduces the organic components. Ultimately this may lead to desertification (Feary, 2011).

Land biodiversity is limited with only 60 species of indigenous vascular plants. A century of mining activity in the interior has resulted in the drainage of large quantities of silt and soil onto the reef, which has greatly reduced the productivity and diversity of reef life. Sewage is dumped into the ocean just beyond the reef.

As with other small island developing State (SIDS), Nauru is highly vulnerable to the impacts of climate change (PACC, 2006). Nauru already suffers from the effects of inter-annual variability in climate and sea-level and any long-term mean changes in temperature and rainfall will further exacerbate the problems being experienced.

2.4 History and culture

There are Micronesian, Polynesian and Melanesian influences in Nauru’s historical and social make-up, but the local language is unique and not clearly related to any other single language. The first recorded sighting of the island was by a British ship in 1798. From 1888 Nauru was administered by Germany but Australia took possession in 1914 and, after World War I, the League of Nations made Nauru a co-trusteeship of Australia, New Zealand and Britain. In 1942, the island was taken over by Japan and occupied for the duration of World War II. After the war, the United Nations re-established Nauru’s trusteeship relationship with Australia, New Zealand and Britain with Australia as administrator. On January 31, 1968, Nauru became politically independent.

The Nauruan culture as we know it today is a combination of Nauruan traditions and traditions adopted from other pacific island states such as Kiribati, Tuvalu and other Micronesian states. Efforts now are being made to research and revive the Nauruan cultural and traditional practices including preserving the language in written form.

2.5 Political development

Nauru has a Westminster parliamentary system with a single chamber of 19 members elected for a three-year term. The parliament elects one of its members as President who acts as both Head of State and Head of Government. Nauru has had frequent changes of government in recent years. Nauru is a member of the Pacific Islands Forum Secretariat and most of the Pacific Island economic and environment associations such as the SPC and the Secretariat of the Regional Environment Programme (SPREP) and is a signatory to most of the economic and environment treaties that affect the Pacific. Nauru became a member of the Commonwealth and the United Nations (UN) in 1999. Nauru has ratified the UNFCCC and the Kyoto Protocol and is currently the chair of the Alliance of Small Island States (AOSIS), a coalition of small-island and low-lying coastal countries that share similar development challenges and concerns about the environment, especially their vulnerability to the adverse effects of climate change. AOSIS functions primarily as a lobbying and negotiating voice for SIDS within the UN system.

2.6 Economic overview

The basis for Nauru’s economy since the early 1900s has been phosphate exports. At the peak of Nauru's phosphate industry in 1975, more than 1.5 million tonnes of phosphate was exported at a price of 68 USD per tonne. After the mid 1990s, production gradually fell reaching almost zero by 2004. Although a Nauru Phosphate Royalties Trust was established to provide income after the phosphate was mined out, poor management of the trust resulted in its rapid depletion, making Nauru essentially bankrupt. Since 2004, successive governments have been dealing with the near-exhaustion of primary phosphate reserves and the legacy of years of economic mismanagement.[2] In 2005, the Nauru Phosphate Corporation became the Republic of Nauru Phosphate Corporation (RONPHOS). RONPHOS then began work on accessing the leftovers from earlier mining and phosphate shipments again began, though at a lower level. Some income flow resumed in 2007 and production in 2009 was 41,549 tonnes. In 2012 phosphate exports from Nauru reached 519,000 tons, the highest annual figure since production recommenced in 2007, and contributed strongly to economic growth of 4.9% in fiscal year (FY) 2012.[3] Phosphate exports are expected to hold steady in FY2014 as mining exhausts primary phosphate reserves and taps into deeper secondary phosphate resources.[4]

In 2009 the country's Gross Domestic Product (GDP) was Australian dollars (AUD) 70 million and the GDP per capita in 2009 was AUD 5,897.[5] Aid is an essential source of funding for Nauru's development.[6] As a percentage of GDP aid receipts are higher in Nauru than any other Pacific Island Country (PIC) – it has been estimated that overseas development assistance (ODA) comprised 31% of GDP in 2008 and 72% of Gross National Income (GNI) in 2009.[7] The population depends on cash incomes and imported goods and employment opportunities are mostly limited to the public sector with the government being the main employer. The country's dependence on highly volatile sources of revenue which includes fisheries licenses and phosphate, has led to a priority to broaden the economic base.[8] Although Japan has assisted in the creation of a local fishery industry, fishing is not a major source of export income and is unlikely to be expanded in the near future.

One of the priorities for Nauru's future development is the rehabilitation of the more than 70% of the island's land area that has been mined (NSDS, 2009). Under the Nauru-Australia Compact of Settlement (NACOS) over rehabilitation of phosphate land mined before independence, Australia paid Nauru $57 million in cash and agreed to provide $50 million over a period of twenty years. The expenditure of these funds is governed by the Rehabilitation and Development Cooperation Agreement (RADCA). Australia and Nauru are cooperating closely on using NACOS funds to facilitate the mining of residual primary and, later, secondary phosphate reserves, followed by the rehabilitation of mined-out lands. However, there has been little visible progress in rehabilitation of mined areas to date.

The reopening of the Regional Processing Centre (RPC) for asylum seekers in 2012 is having an impact on construction, hotels and accommodation, restaurants, and retail trade, as well as increasing government finances (ADB, 2013). In the long term sound management of phosphate wealth and of revenues from the reopening/planned expansion of the RPC will largely determine Nauru's fiscal and economic sustainability.

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[2] *Asian Development Bank & Nauru Fact Sheet*, 31 December 2012

[3] *Asian Development Outlook 2013 – Asia's Energy Challenge*, ADB, p. 281, 2013

[4] *Pacific Economic Monitor*, p. 8, July 2013

[5] *Nauru: Updating and Improving the Social Protection Index*, ADB, p.4, August 2012

[6] The major donor to Nauru is Australia, which has supported Nauru's reform programmes in finance and governance, education and training, health, utilities, fisheries and law and order.

[7] *Millennium Development Goals - Nauru Progress Report 1990-2011*¸Government of Nauru, p. 73, August 2012

[8] *Nauru Economic Infrastructure Strategy & Investment Plan*, Government of Nauru, P. 7, November 2011

3 Energy sector overview

3.1 Introduction

With the decline of its phosphate resource, Nauru remains in a difficult transitional stage between extraordinary national wealth and a return to the resource-poor situation faced by several of the smaller Pacific island nations.

In the energy sector, Nauru is moving along in a process of shifting from what amounted to a system of free electricity to tariffs that recover the real cost of power. At the same time the power system comprises a power station dating back to the early 1950's with diesel generators ranging in age from 10 to 37 years old and a distribution system also dating back many decades, all of which urgently need overhaul and replacement. Donor inputs, particularly from Australia, the European Union and Japan, into the power sector have been substantial generous and have enabled an electricity service to the population to continue, albeit with frequent problems.[9]

A National Energy Policy Framework (NEPF) has been in place since 2009 and the government has established goals for the increased use of renewable energy (with a target to reach 50% of the overall supply) and improved efficiency on the part of both the utility and energy customers.

To help coordinate this transition and help relieve Nauru from its almost total dependence on fossil fuels, in 2012 the government requested technical assistance from GIZ, SPC and IRENA to develop an Energy Road Map to set and achieve energy sector goals.

3.2 Energy Supply and Demand

3.2.1 Petroleum

The average amount of petrol purchased by the government for its own use and for distribution is around 1.5 ML a year. Automotive diesel oil (ADO) is around 8.8 ML and jet fuel around 1.3 ML. The government regulates the re-sale price of fuels with revisions every shipment. The Government has frequently relied on grant funding from Australia and Japan for the purchase of petroleum imports for the power sector. Even so, shortages have occurred due to a lack of funds in the government budget to make timely purchases, resulting in fuel rationing and rolling blackouts of electricity.

Table 1 - Government fuel imports 2006-2010 (Litres)

Fuel Type	2006	2007	2008	2009	2010
Actual Diesel	8 144 167	5 334 340	8 074 821	8 671 864	8 842 138
Actual Petrol	1 092 549	1 164 518	1 409 669	1 447 507	1 467 753
Actual Jet Fuel	520 245	954 996	963 200	N/A	N/A

Source: NUC, 2012

Diesel fuel and petrol are stored and distributed by NUC to all users except RONPHOS who maintains a separate diesel fuel storage facility and often purchases and imports diesel for their industrial use. Jet fuel is used only by the national airline,

[9] From circa 2005 to 2009 Nauru experienced scheduled rolling black-outs. From late 2009 a 24 hour electricity service was restored, although brown-outs and black-outs are still regular occurrences.

Our Airline, though NUC manages its storage along with that of other petroleum products.

Retail prices for diesel were reported at 1.72 AUD/litre (SPC, 2013), while NUC purchases diesel for electricity generation at 1.23 AUD/litre. This compares with an average retail diesel price of 1.62 AUD/litre across the Pacific Islands as shown in Figure 2~~Figure 2~~ below (SPC, 2013).

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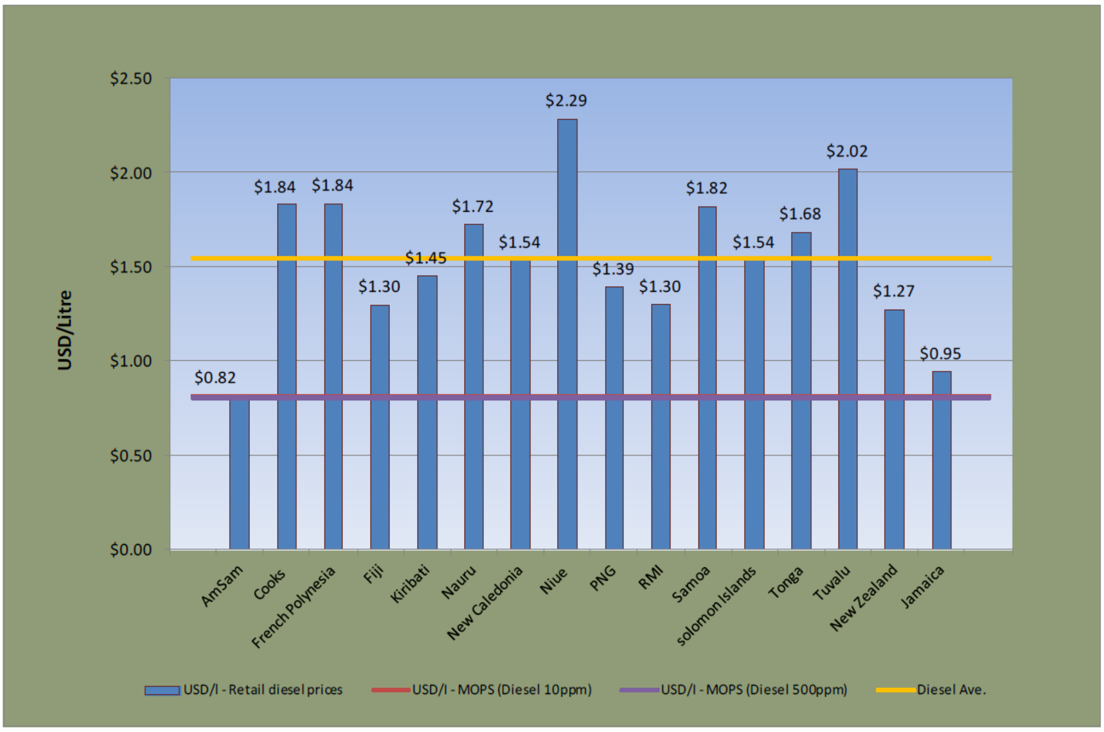

Figure 2 - Average retail diesel prices in PICTs
Source: Pacific Energiser, Issue 11, April 2013

3.2.2 Liquid Petroleum Gas and kerosene

Liquified petroleum gas (LPG) was used by 31% of households as their main fuel for cooking in 2011 (NBoS, 2013). It is also reportedly being used for cooking by restaurant businesses although there is no data on quantities or number of restaurants using LPG for cooking. It is provided by two private importers, Central Meridian (CMI) and Capelle & Partner (LAVA GAS). Retail prices were observed to be in region of 60 AUD for an 11kg cylinder. Kerosene is used as the main fuel for cooking by 3.1% of households. The retail price for kerosene was observed as 7 AUD per litre[10].

In 2009 the cost of LPG in Nauru was the highest in the region, approximately twice the average price and triple the lowest price (Fiji). The subsidized electricity tariff, conversely, is the lowest in the region (USD 0.10 / kWh), making the use of electricity for cooking artificially cheaper than LPG, at a high cost for the government budget.

[10] Observation made in retail outlets during SPC-GIZ CCCPIR technical mission, November 2012

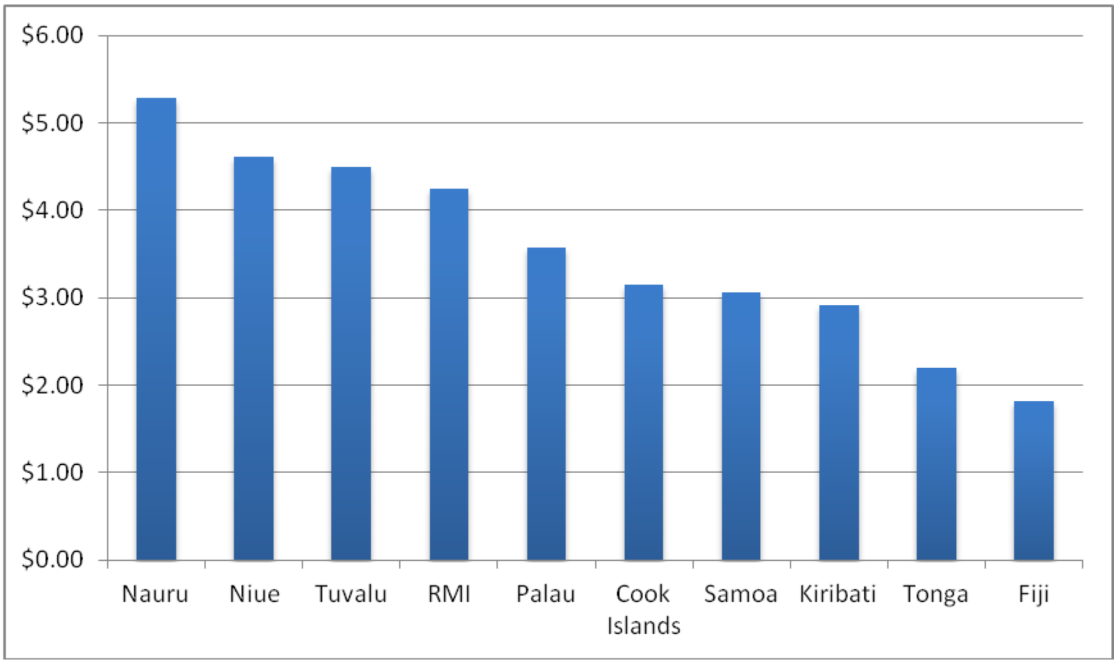

Figure 3 - LPG retail prices in US$/kg
Source: SPC, Energy Security Indicators 2009

3.2.3 Electricity

3.2.3.1 Electricity supply

Nauru's electricity supply comes from a single power station operated by NUC. Most of the power now comes from four ageing medium-speed Ruston stationary engines with a high-speed Cummins generator providing essential supplementary capacity. There are plans to repair and install two more generators which are already in Nauru but not in use. Table 2~~Table 2~~ below provides information on the NUC generators.

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Table 2~~3~~ - Installed Diesel Capacity

Generator Type	Rating (MW)	Speed (RPM)	Year Installed	Running Hours[11]	De-rated Capacity (MW)
#1 Ruston	2.6	750	1989	32,616	1.0
#4 Cummins	1.0	1,500	2008	19,032	0.35
#5 Ruston	1.0	750	1976	19,626	Out of Service
#6 Ruston	2.0	750	1977	26,070	1.6
#7 Ruston	2.8	750	2008	26,435	1.6
#? Ruston 16RK3C	2.0	750	TBC	To be installed	-
#3 Caterpillar	1.4	1,500	TBC	607	-
Total	**12.8**				**4.55**

Source: NUC, August 2013

Maximum demand was once in excess of 7 MW but has dropped, largely due to the loss of industrial demand, to between 3.6 to 3.8 MW (NUC, 2013). The existing diesel engines have a nameplate total of 12.8 MW power generation capacity, but have been de-rated to 4.55 MW. This is enough to meet demand but if any one engine breaks down, load shedding is necessary. This also means that NUC does not

[11] Since last overhaul

currently have sufficient capacity to carry out planned or scheduled generator maintenance without causing load shedding.

The 2011 Nauru Economic Infrastructure strategic Investment Plan (NIESIP) called for the establishment of an O&M spare parts store and workshop for NUC to enable more regular and timely maintenance of its generator sets and reduce lead time for spare parts. However, there has been no progress on this project to date and AusAID is providing spare parts and equipment on an ad hoc basis.

The distribution system is in a ring main configuration and includes 11 kV, 3.3 kV and 415 V sections. There are 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 overhead transmission/distribution network is ageing and large parts are in need of overhaul and/or complete replacement. 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. NUC also plans to look at replacing and upgrading various transmission/distribution equipments with funding from the EU to cater for future load growth and future renewable energy generation that is connected to the grid.

3.2.3.2 Electricity demand

Currently the grid maximum demand is between 3.6 and 3.8 MW (NUC, 2013). During the years of high phosphate production, industrial use dominated the Nauru energy economy. That use has diminished and the domestic sector is now the dominant user.

Table 3 - Total generation and fuel use 2008-2010

Year	Actual generation MWh	Fuel used (litres)
2008	19 382	5 929 740
2009	21 174	6 299 460
2010	22 462	7 181 100

Source: NUC, 2012

Daily load curves for 2010, as shown in Figure 2 below, indicate a weekday baseload of around 2MW and an evening peak of around 3.2MW, probably due to cooking using electric ovens (60.2% of households). The weekend load varies from around 2.5 to 3MW with the peak again in the evening. There is little demand for water heating but a substantial demand for cooking is still present though electric cooking has been replaced by LPG to some extent (31% of households) or by kerosene cooking (3.1% of households). The use of LPG or kerosene despite their high retail price can be explained by the continued unreliability of the electricity grid, making LPG an attractive option to provide a reliable source of energy for an essential activity such as cooking. Households switching between different sources of energy for cooking depending on whether electricity is readily available has also been observed.

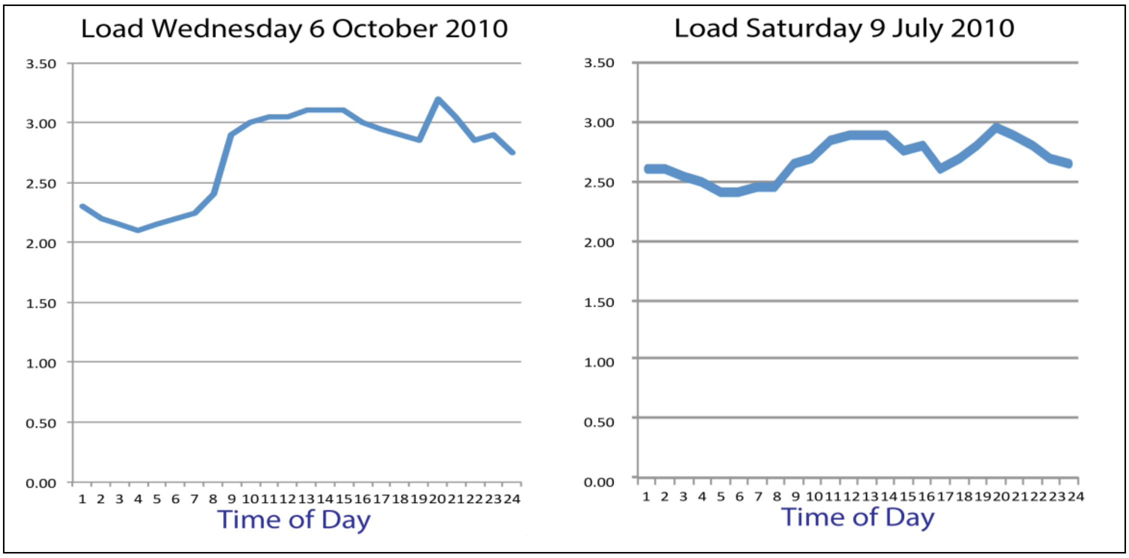

Figure 4~~3~~ - Load curves for 2010

Source: NUC, 2011

RONPHOS has offices and 18 staff houses which are still connected to the NUC grid. The offices are estimated to consume 100 kWh / day. The RONPHOS large mechanical equipment and drying kilns are powered by their own generators on an as-needed basis. RONPHOS has a 1.8MW generator for its production facility and a 0.8MW generator for primary crushing and screening (which runs at about 45% of capacity). Both run for 20 hrs /day, 12 days a fortnight.

RONPHOS occasionally draws additional electricity from the grid for its operations, specifically when phosphate loading is carried out. This has lead in the past to load shedding on other parts of the island so that RONPHOS power demand can be met. There have been occasions when NUC has not been able to supply RONPHOS demand.

3.2.3.3 Electricity tariffs

Because electricity tariffs have been kept artificially low and bill collection was not enforced, the average household use of electricity is very high, estimated at around 400 kWh/month (although there is likely a significant variation between households). 29% of homes own air-conditioners, though there is no data on type, size or extent use of use. Other common electrical appliances are televisions owned by 75% of households, refrigerators (57%), deep freezers (48%), computers (46%) and fans (93%) (NBoS, 2013).

To gradually shift the population to paying for electricity, prepaid meters have been installed since 2009 for most domestic and commercial customers. Some domestic and most commercial, government and industrial customers are still on standard post-pay meters with a list of post-paid meters provided in Table 4 below.

Table 4 - Post-Pay meters in Nauru (2011)

District	District Name	total	Domestic	Commercial	Government	Industrial
1	Aiwo	**46**	15	23	2	6
2	Anabar	**4**	0	4	0	0
3	Anetan	**3**	0	2	1	0
4	Anibare	**2**	0	2	0	0
5	Baitsi	**5**	1	1	3	0
6	Boe	**3**	0	1	2	0
7	Buada	**2**	1	1	0	0
8	Denig	**26**	17	6	3	0
9	Ewa	**1**	0	1	0	0
10	Ijuw	**0**	0	0	0	0
11	Meneng	**13**	5	4	4	0
12	Nibok	**4**	1	1	2	0
13	Uaboe	**0**	0	0	0	0
14	Yaren	**14**	1	6	6	1
	Total	**123**	**41**	**52**	**23**	**7**

Source: NUC, 2013

The tariff is still heavily subsidised, with a residential rate of AUD 0.10/kWh (USD 0.10) up to 300 kWh (lifeline threshold) and AUD 0.25 (USD0.23) per kWh for additional energy. It should be noted that 300kWh is very high a lifeline allocation. Commercial customers pay a flat rate of AUD 0.30/kWh (USD 0.27). The industrial (phosphate) rate is AUD 0.50 (USD 0.46) per kWh and the government is now also being charged at AUD 0.50 per kWh (up from AUD 0.20/kWh in 2010).

Full cost recovery is estimated to be between 0.45 and 0.49 AUD (0.51 USD) per kWh at the 0.85 AUD (0.87 USD) per litre price in November 2011, so the subsidy to residential and commercial customers is significant. RONPHOS and the Government are paying for electricity at a cost-recovery tariff. The total overall subsidy could be gradually reduced as customers become more energy-efficient and fewer kWh have to be subsidised even if tariffs and energy costs remain unchanged.

Table 5 - Customer Meters (2011)

Sector	Number of prepaid customers	Number of billed customers
Residential	1980	42
Commercial	124	48
Industrial	0	2
Government	0	32

Source: NUC, 2012

Even though there are only 20 public streetlights on Nauru and their consumption is very small, conversion to high-efficiency LED lights is being considered. These lights are not metered and the cost for running them is born by NUC.

3.2.4 Future growth in energy demand

Due to the major structural changes taking place in the Nauru economy, particularly the reopening/expansion of the RPC, accuracy is very low for forecasting future energy use. It is possible that fuel use will not increase, and may even decrease, over the next decade as electricity prices are increased from the heavily subsidised levels of today to a tariff that recovers full cost. Also, industrial fuel use is closely tied to phosphate production, which has a long-term downward trend. On the other hand fuel use could increase if the RPC starts drawing power from the main grid and if population increases due to the construction, retail and other impacts of the RPC. Also if the activities of NRC expand and more machinery or office equipment is needed this could imply higher future energy use. The use of jet fuel may have significant growth over the next 10 years but this is only likely if Our Airline (the national airline of Nauru) expands its operations, which is an uncertain scenario.

3.2.5 Energy security

A UN ESCAP report released 2012 stated that "*The dependence of Pacific countries on fossil fuels for their energy needs presents a major threat to energy security and economic stability*."[12] This statement holds true for Nauru which is currently extremely depended on imports for all its energy use and as has very high exposure to fuel price volatility. With its very limited land area and mining out of a large part of this, traditional use of biomass for cooking is limited (only 6% of households use wood or open fire as their main cooking fuel according to the 2011 Census) and potential for biofuel development is very limited at least in the near future. Alternatives such as kerosene and LPG are expensive imports. Electricity generation is also 99% dependent on imported fuel. Solar energy is the only proven renewable energy resource which could be utilised in short to medium term to reduce dependency on fuel imports for electricity generation. The country's vulnerability is also increased by its isolation from other Pacific Islands.

In 2012, SPC released an energy profile of Nauru based on 36 energy security indicators. While Nauru ranked high compared with other Pacific Small Island States (SIS) in some indicators such as electrification (100%, compared to a SIS average of 68%) and affordable tariffs (14USc/kWh compared to a SIS average of 36USc/kWh), it had low scores for renewable energy share in the overall energy mix at 0.05% and only an estimated 73 days of fuel supply security. No significant programmes have been put in place to improve demand side energy efficiency (SPC, 2012).

3.3 Institutional, regulatory and legal arrangements for energy

3.3.1 National Sustainable Development Strategy

The NSDS is a 20 year plan that provides a roadmap for Nauru's development. The NSDS articulates the national vision, goals, strategies and priorities of Nauru and presents where Nauru wants to be in the medium term (5 to 10 years) and long term (10 – 20 years). The theme of the NSDS is *"Partnerships for Quality of Life"* (NSDS, revised 2009).

Energy within the NSDS is included under the broader priority sector of "Infrastructure" with a priority of: *Provision of enhanced utilities and transport services including the increased use of renewable energy, power (non-diesel generation i.e. OTEC and solar), water, waste management, roads, sea and air services".*

[12] Green Economy in a Blue World: Pacific Perspectives, ESCAP, September 2012

3.3.2 Nauru Energy Policy Framework

The Nauru Energy Policy Framework, developed and endorsed by the Nauru Government in 2009, was integrated into the revised NSDS (2009). The NSDS includes a goal for the energy sector to “Provide a reliable, affordable, secure and sustainable energy supply to meet socio-economic development needs” and includes energy under its major priorities and states that “whilst there has been considerable progress in achieving more stable electricity … services, the current way in which electricity … services are delivered is not sustainable for Nauru. Urgent measures need to be taken to upgrade infrastructure, raise efficiency, secure the benefits of renewable energy”.

The 2009 Energy Policy Framework vision statement is *“Reliable, affordable and sustainable energy, enabling the social-economic development of Nauru”.* The NEPF has seven strategic policy areas:

1. Power
2. Petroleum
3. Renewable Energy
4. Consumers
5. Finance
6. Institutional capacity
7. Energy conservation and efficiency

Under each policy area, there is a policy statement and broad strategies; although no specific activities are laid out.

3.3.3 Nauru Utilities Corporation

Until 2005, the Nauru Phosphate Corporation provided all the island’s electricity and water services. In 2005 the Nauru Utility Authority (NUA) was formed to separate the water and electricity utilities function from the phosphate corporation. It was later decided to corporatize NUA and the Nauru Utilities Corporation (NUC) was created.

In June 2011, the status of the utility as a corporation was formalised with the passing of the Nauru Utilities Corporation (NUC) Act 2011 which states the legal obligations of the utility. Under the Act, the CEO of NUC reports directly to the Minister of Utilities. The current organizational structure of NUC is shown in Figure 5~~Figure 3~~ on the following page.

It should also be noted that although the NUC Act sets up the aims and responsibilities of the utilities corporation, it does not provide for all the legislation and regulations needed for everyday operations. The NUC Act includes a limited number of regulations that deal with recovery of fees from post paid customers and with a small number of operational issues such as providing the power of entry of NUC staff to enter land and buildings to undertake functions of the utilities. Therefore, there is a need for additional subsidiary legislations and regulations to further guide the day-to-day operations of the utility.

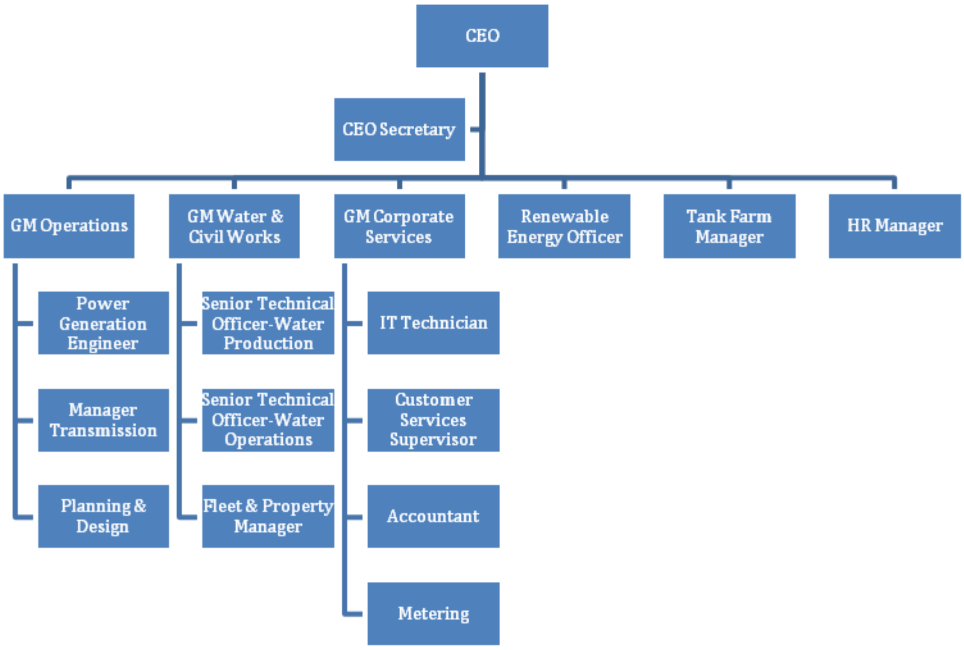

Figure 5 - Organizational structure of NUC

In 2012 NUC developed a Corporate Strategy with technical assistance from the Asian Development Bank (ADB) including vision, objectives and performance indicators. Priority areas identified in the strategy include: power generation and distribution systems, research and implementation of renewable energy projects, energy efficiency, improved tank farm management and overarching financial management and control and capacity building.

The NUC currently provides all electricity services to Nauru except for the RPC and the main processing plant of RONPHOS which both generate their own power. Diesel, petrol and jet fuel are purchased by the government for all customers except RONPHOS who do their own purchasing. The diesel, petrol and jet fuel are stored and distributed by NUC to all users except RONPHOS who maintains a separate diesel fuel storage facility for their industrial use. Jet fuel is used only by the national airline, Our Airline, which purchases it from the government. LPG and kerosene are privately imported and distributed.

3.3.4 Government institutional arrangements

With regard to the institutional framework for energy policy-making, planning and regulation within government, there have been very limited resources dedicated to the energy sector to date with responsibility for energy policy being allocated to the Environment Division of the Department of Commerce, Industry and Environment (CIE). There is no single staff with responsibility for the energy sector and this has been managed by CIE staff largely on an “as needed” basis under the direction of the Secretary of CIE. However, as part of the ongoing process of the development of the Nauru Energy Road Map, an Energy Coordinator is currently being recruited to be located in CIE. An approximate institutional mapping of the energy sector is given in Figure 4 below.

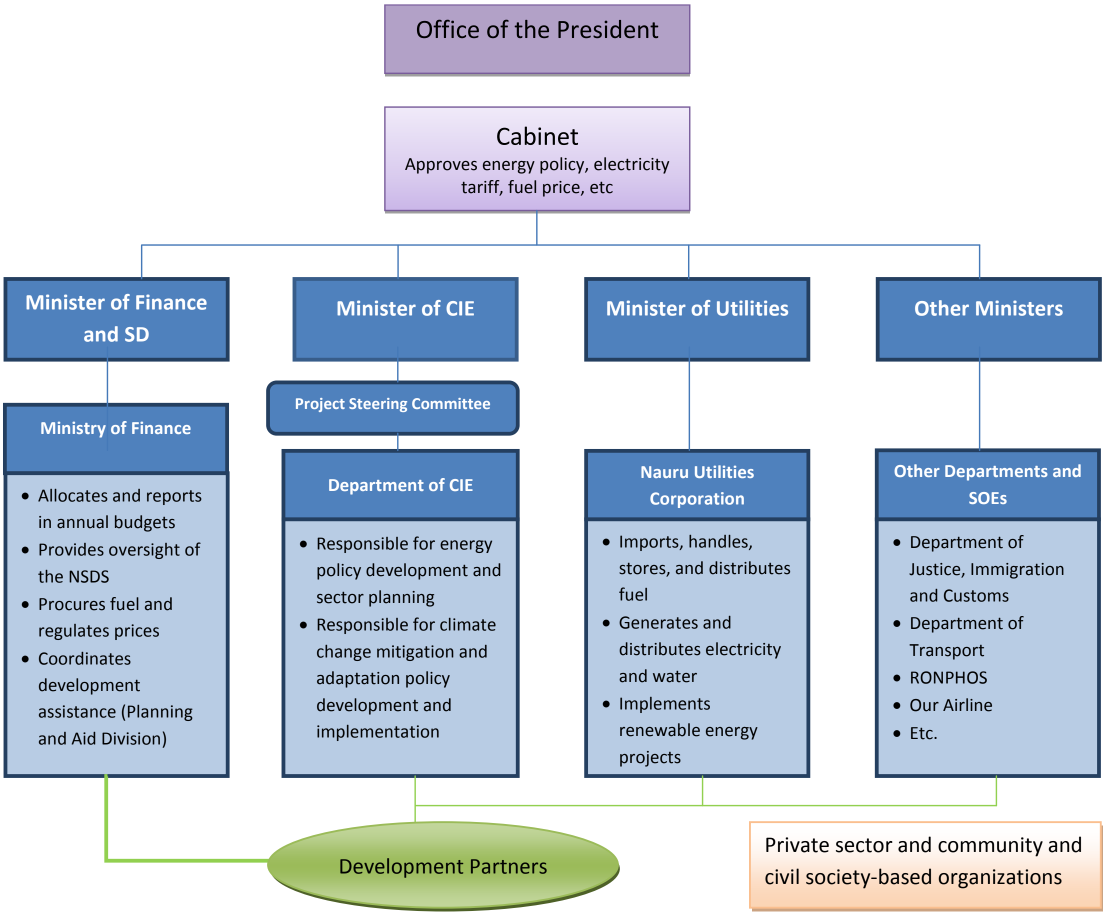

Figure 6 - Energy institutional map

Since 2004, development partners have made significant contributions to the energy sector. Funding for equipment, technical assistance and fuel procurement is channelled through the Ministry of Finance but as the diagram shows there is also some technical assistance channelled to other sectoral departments such as energy which does not always go directly through the Department of Finance.

Although CIE has the responsibility for energy policy and planning, there is no dedicated staff at present. A Renewable Energy Officer is employed by NUC and is primarily responsible for renewable energy project implementation and for energy efficiency campaigns. There is also an Assistant Renewable Energy Officer, although this position does not seem to be formalised as it does not appear in the organisational structure of NUC (see figure 4).

The first mention of renewable energy in national policy appears in the 2005 NSDS. However, after this there is no further mention of renewable energy in any legislation, regulations or corporate actions until the 2009 Nauru Energy Policy Framework. An Energy Efficiency Action Plan was drafted in 2008 but was not officially endorsed, although many of the recommended actions were undertaken.

A list of key energy-sector related policies and legislations is given in Table 6~~Table 6~~ below.

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Table 6 - Key policy, legislation and strategic planning documents

Year	Legislation, policy, strategic planning document
2005 (rev. 2009)	National Sustainable Development Strategy 2005-2025
2006	Nauru's Utilities Sector – A Strategy for Reform
2008 (draft)	Nauru Energy Efficiency Action Plan 2008-2015
2009	National Energy Policy Framework
2011	Nauru Utilities Corporation Act
2012	Nauru Economic Infrastructure Strategic Investment Plan
2012	Nauru Utilities Corporate Strategy

Currently Nauru is working on an Energy Road Map, including action plans for the development of renewable energy and energy efficiency sufficient to significantly lower imports of diesel fuel for electricity generation.

3.4 Financing of the energy sector

There is limited data on national Government of Nauru budget allocations that are dedicated to the energy sector as budgets are divided by Departments and there is no specific department for energy as this falls under CIE. There is an annual contribution to purchasing of fuel for electricity generation; however, it is unclear how much of this is covered annually by the Government of Nauru's own funds and how much by contributions from development partners such as Japan and Australia.

Development partners make a significant contribution to funding for energy sector projects covering a wide range of areas from petroleum to power sector reform and including renewable energy and energy efficiency. These contributions can be tracked to some extent through the development partner monitoring processes, including progress reports and final project reports. An indicative and non-exhaustive list of development partner assistance to the Nauru energy sector is given in Annex 1 to this report. This list includes data estimated from various available sources and may not accurately capture all the programmes and projects; however, it is used here on an indicative basis.

This information indicates that by the end of the period 2004 to 2017 a total of approximately 79 million USD will have been made available in support to energy sector activities. Using the estimated amounts for funds that have largely already been disbursed or are confirmed to be committed from 2004 to 2013, Figure 5 shows that there have been increasing levels of contribution to energy sector projects over the last decade from around 4 million USD / year to approximately 8 million USD / year.

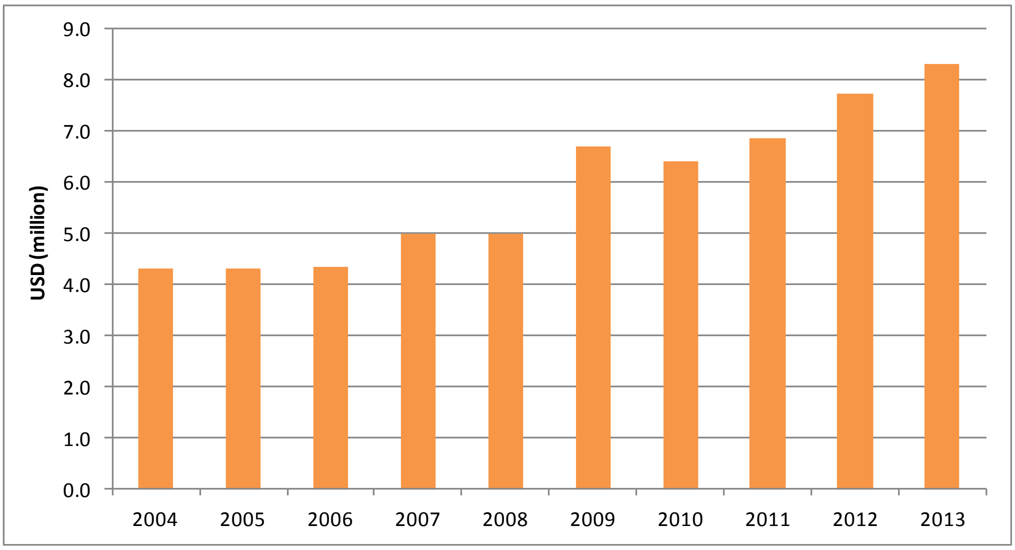

Figure 7~~6~~ - Estimated funds already disbursed or committed 2004 - 2013

The majority of the funding identified (65 million or 82%) between 2004 and 2017 is allocated towards fuel for electricity generation and essential power sector maintenance activities. The remainder funds various supply-side and demand-side energy efficiency projects and renewable energy installations (mainly solar PV) as well as technical assistance including energy sector studies. Figure 6 presents a breakdown of the contribution between different development partners.

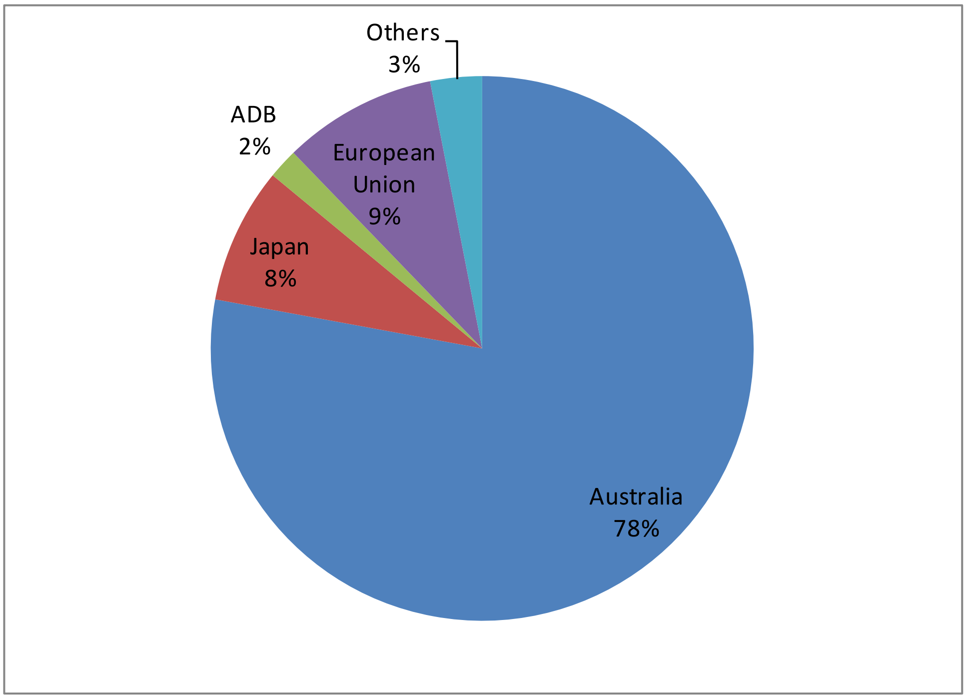

Figure 8~~7~~ - Estimated contributions from development partners to energy sector 2004-2017

It should be noted that while this is the amount of funding estimated to be available, it may be that Nauru does not access all available funds due to administrative and other constraints.

3.5 Monitoring framework

There is a no comprehensive framework for monitoring and evaluation of progress in the energy sector, although monitoring and evaluation does take place at the project level to satisfy reporting obligations to development partners. Ad hoc assessments of the energy sector are periodically funded by development partners on request from the Government of Nauru or carried out by regional energy organisations as part of regional energy sector assessment projects. Often these assessments focus on a particular sector, such as the Pacific Power Association (PPA) Benchmarking Report focussed on the power sector.

The NUC Corporate Strategy developed in 2012 summarizes the major strategic directions NUC will pursue over the coming three to five years. It includes specific objectives and Key Performance Indicators (KPIs) with the aim to achieve outcomes related to each objective within set timeframes.

Some monitoring is also done indirectly as part of the NSDS review, which includes energy under the section on Infrastructure. The NSDS was launched in 2005 and is required to be reviewed every 3 years. There was a review in 2009; however, the next review has been postponed to 2014.

There is also some monitoring and evaluation of the energy sector through the annual process of planning and budgeting which is undertaken with AusAID.

4 Renewable energy

4.1 Renewable energy opportunities

The 2005 National Sustainable Development Strategy (NSDS) and the 2009 Energy Policy Framework both state Nauru's aim to make 50% of energy provided through renewable energy by 2015.

The development of a 'Strategy for Renewable Energy' was included in the 2011 Nauru Economic Infrastructure Strategy and Investment Plan (NEISIP) with the aim to progressively replace the use of fossil fuels with solar energy.

Solar. Measurements show an average of over 6 kWhr/m^2/day (with solar panels tilted to the angle that maximises energy input) with a seasonal variation of around 10-15%. Although solar PV offers electricity generation that can supplement the existing diesel generation, due to the intermittency of the resource, expensive electrical storage systems will be required for it to be included into the grid at high levels of penetration. A dynamic model has not yet confirmed the maximum possible level of solar penetration before grid stability issues occur, but it is likely to be limited to around 20% - 30% of the midday demand. Above this threshold storage and control systems will probably have to be introduced to ensure grid stability. This still means that currently as much as 1 MWp of solar PV could be installed although this would be a large infrastructure investment, even without storage. In terms of energy production, a 30% midday demand penetration represents around a 5% yearly energy penetration for the conditions in Nauru.

Wind. Data collection, funded by PIGGAREP and the EU[13], has been carried out for more than three years at a telecommunications tower at Anabar District on the northern part of the island where the wind resource is expected to be greatest (based on an indicative study carried out in 2006 by Winergy). However, the telecommunications tower includes components near the wind measurement instruments that may change both the speed and direction of the wind seen at the instruments thus lowering the confidence in the data collected to date. Measurements collected and analysed over one year indicate an annual average wind resource of 4.22 m/sec at 30 meters (about 4.7 m/sec if extrapolated to 50 meters) for 2009-2010 (SPREP, 2010). These figures are at the low end of practicality for wind energy generation. A resource assessment using a more suitable 50 metre guyed mast is underway and is intended to determine the appropriateness of further wind energy development and to assess the quality of the data already collected from the nearby telecommunications tower.

Biomass. With little or no biomass present at topside, there are insufficient biomass resources for either combustion for electricity or significant production of biofuels. Land rehabilitation may eventually result in topside biofuel plantations if suitable fast growing plants can be grown in the rehabilitated area, but certainly no production will be seen within the next decade. There may be scope for domestic-scale piggery biogas projects for cooking but the number of pigs needs to be quantified before the level of contribution to the energy mix from biogas can be assessed.

[13] PIGGAREP funded the first 12 months (2009-2010) of the wind data collection. The EU funded an additional two years (2010-2011).

Wave. Wave energy in the equatorial region is low with around 10-15 kW/m estimated from satellite observations. Wave devices are being tested at the prototype stage around the world, however, none are yet commercially proven. Even if wave conversion systems become commercially available, the low resource will make it difficult for Nauru to economically develop wave power.

Ocean Thermal Energy Conversion. With the very rapid drop-off that occurs beyond the reef, there is an opportunity for OTEC energy development once engineering and commercial trials are completed elsewhere. However, it does not appear likely that OTEC can be a part of the Nauru energy economy within the next 10 years, since there still are no OTEC plants anywhere in the world currently producing electricity. Further details of OTEC trials and potential in Nauru are available in Annex 2.

4.2 Experiences with Renewable Energy Technologies

Less than 1% of Nauru's electricity is currently generated from renewable resources. Installations over the years have included:

- Solar water heating was used to some extent in the 1980s but most of the systems failed after a few years of use and were not repaired. Currently there is little demand for water heating systems. However those few households presently using electric tank type electric water heaters should be encouraged to replace them with either demand type electric water heaters or, preferably, solar water heaters.
- The Japanese utilities company TEPCO undertook a technical trial of OTEC in 1981 with an experimental plant on the west coast of Nauru that produced a net power of 15 kW for a short time before being damaged by a storm. The trial was mainly designed as a proof of concept to gain experience with the technology and it has not resulted in further development of OTEC in Nauru.
- In 2008, the REP-5 project of the EU installed a 40 kWp grid-connected installation on the roof of Nauru College. NUC states that the installation produced 213,597 kWh from October 2008 through September 2012. This gives a specific yield of 1335 kWh / kWp per year.
- Sixty solar home systems of 130 Wp capacity, which included LED lights, have been provided by Chinese Taipei institutions though their operational status is not known. All were installed on homes already connected to the grid so only the lighting load is affected.
- Chinese Taipei institutions also funded a solar street lighting project which included 155 units installed around the island following the main road, with some of the larger units installed in community areas and government buildings and smaller units installed in less travelled residential areas. However, these have not been maintained and many are no longer operational.
- Although some 160 Wp arrays for solar-powered district water pumps have been installed through JICA funding, details of their number and status are not available.

- A few households have private solar water pumping systems, although the number and capacity of these is not known.
- Solar PV and small-wind turbines with batteries were installed on power poles sometime in 2009 with the intention to power the telecommunications system. However, the project was not completed as intended and some of the batteries were used for alternative purposes, while some of the solar PV panels remain unused.
- Solar powered torches with LED lights donated by ~~Taiwan~~ Chinese Taipei were recently distributed to households. Further information was not available at the time of writing.
- In 2011, twenty solar stills for water purification were purchased and installed on private residences in areas with a particular vulnerability to water shortages.
- A grid-connected PV system with an installed capacity of 15.84 kWp was provided by Chinese Taipei and installed at the government offices building in 2012. In late 2012 this was expanded to a total of 30kWp.
- In 2013, the PEC fund of Japan financed a grid-connected solar installation of 132 kWp which was installed across two roofs on government buildings near the NUC power plant to offset the electrical energy needed to operate the new reverse osmosis (RO) plant also installed through the PEC fund in early 2013. The solar PV is located on two buildings next to the NUC RO plants at the back of the NUC power plant. The main solar array is located on a RONPHOS warehouse (adjacent to the RO plants) and the rest of the solar is on the building just in front of the RO plants which houses the RO water settling tanks. Operational data on the solar PV system is not yet available.[14]

A summary of renewable energy projects in Nauru is given in Table 6 below.

[14] A clarification should be made here that there is no "solar-powered RO system" installed. The PEC fund project provided grid connected solar the designers claim is sufficient to *offset* the energy required by the RO plant they provided but the solar is *not* connected to the RO plant. The RO plant runs off the grid electricity and the 132kW solar feeds the grid. If the solar fails, the RO plant still works with no change as it draws its power directly from the grid but if the grid power fails the RO plant cannot function. Whether the solar provided actually does offset the amount of energy used by the RO plant is not something that can be easily answered since the amount of hours per day that the plant is operated will determine the energy usage and that is not known in advance. It can really only be determined on a historical basis by checking energy output from the grid connected solar and the use of energy by the RO plant. However, the 132 kWp of solar is likely to offset most if not all of the energy used by the newly installed RO plant.

Table 7 - Summary of past, current and proposed renewable energy projects

Technology	Installation Date	Capacity	Implementing Entity	Funding Entity	Operating in 2013
Solar Water Heaters	1980s	Unknown	GoN	GoN	No
OTEC	1981	150 kW gross, ~15kW net	TEPCO	Japan	No
Grid Connected solar PV	2008	40 kWp	GoN/NUC/IT Power	European Union	Yes
Solar PV and small wind turbine system	2009	Unknown	GoN	Unknown	No
Solar home systems	2010	7.8 kWp (60 SHS at 130 Wp each)	GoN/NUC	Chinese Taipei Inst.	Yes
Solar street lights	2011	155 units (130Wp)	GoN/NUC	Chinese Taipei Inst.	Some
Solar water pumps	Unknown	160Wp (quantity unknown)	GoN/NUC/ private	JICA/private	Yes
Solar LED lights	2011	Unknown	GoN/NUC	Chinese Taipei Inst.	Unknown
Solar stills	2011	20 units with 4 panels per unit	GoN/PACC project	GEF	Yes
Grid connected solar PV	2012	30 kWp	GoN/NUC	Chinese Taipei Inst.	Yes
Grid connected solar PV	2013	132 kWp	GoN/NUC	PEC Fund	n/a
Grid connected solar PV	Proposed	1 MWp	GoN/NUC	Unknown	n/a

As can be seen from the table, the main renewable energy technology deployed in Nauru to date has been solar PV (both off-grid and grid-connected), with only minimal experience with other technologies (OTEC, solar water heaters, solar stills, wind).

4.3 Challenges for renewable energy deployment

As evidenced by the slow progress in development of renewable energy in Nauru over the past 30 years, there are a number of challenges to deploying renewable technologies on the island. Some of these challenges are typical of Pacific Small Island States and other small islands around the world; others are specific to the context of Nauru. Below some of the challenges that are more specific to Nauru are listed although this is not an exhaustive list:

- Limited human capacity to meet the technical requirements for complex project proposals and project management by potential renewable energy financing institutions.
- Lack of data to design project proposals and plan renewable energy systems.
- No single agency in government has responsibility for renewable energy development.

- High cost of access to the island.
- Land tenure issues may be a problem for large-scale installations.
- Nauru's high ambient temperatures, moisture, UV exposure, coral dust and high levels of atmospheric salt create a difficult environment for electrical and mechanical equipment.
- Lack of adequate technical capacity for maintenance and repair.
- Small population, with few resulting economies of scale.
- Limited knowledge of renewable energy at all levels of government.
- Lack of a realistic and well-defined action plan to achieve fuel import reduction targets.
- There is a need for a grid stability study.
- The utility (NUC) is in transition and a declining load is possible as industrial use declines while tariffs rise and users adopt energy-efficiency measures. Any renewable energy that is added now should consider this possibility and be capable of being upgraded to include either advanced controls or storage that reduces the rate of variation even though it may not be needed at present.
- Current status of diesel power station does not allow relevant shares of intermittent renewable energy (i.e. solar PV, wind) to be integrated without major improvements in the control systems. There is a need to consider improving controls as well as introducing appropriate levels of storage (i.e. batteries).
- Limited to no potential for dispatchable renewable energy power generation (i.e. biomass, hydro, geothermal, concentrated solar power).

5 Supply Side Energy Efficiency

For a power station, supply side energy efficiency is determined by the ratio of kWh delivered to loads to kWh generated at the alternator. It includes all station usage such as energy to operate fuel transfer pumps, control systems, cooling fans and other equipment in the power house. It also includes all losses that occur in transformers, switchgear and the transmission and distribution wiring. Two main classes of supply side losses are usually measured, technical and non-technical system losses.

Technical losses are those that relate to the difference between energy generated and energy actually delivered to a load somewhere on the system. Non-technical losses relate to the difference between energy delivered to loads on the grid and energy actually paid for by customers on the grid (energy sales). Technical losses directly affect the import of fuel needed for generation on a per kWh basis. Non-technical losses affect the financial return to the utility and the tariff required to be charged to paying customers in order to recover the overall cost of energy delivery.

In the case of Nauru and the development of the Energy Road Map, engine fuel efficiency – the number of kWh generated per litre of fuel – is also a measure of supply side efficiency that must be included in the analysis.

5.1 Supply side energy efficiency opportunities

In 2012, a PPA sponsored study determined that NUC has a relatively low internal energy use of 2.27%, a somewhat high 4.43% for technical losses and a very high 15.77% non-technical loss which includes unbilled usage. Non-technical losses are primarily financial losses and though their reduction will improve the financial condition of NUC, they have little effect on actual energy production or use though of course in the long term the utility will be unable to provide a high quality of service if it cannot maintain an adequate financial return.

Losses in un-billed usage, notably streetlights, can be significantly reduced by replacing existing equipment with energy efficient units. NUC’s electricity transmission system is old and overall distribution losses could also be reduced by simple replacement of worn out equipment (high-voltage transmission switches, circuit breakers, etc.), but the large investment required needs to be economically justified by the energy savings that will result. The EU are funding a rehabilitation project, which includes procurement and installation of equipment to the value of 2.3m Euros. NUC management would like to see a complete rebuild of the system moving the overhead system to below ground.

A general survey of the existing distribution system should be carried out and, if shown to be economically reasonable, a plan prepared for upgrading and/or changing to an underground system. This would allow better management of energy flows in the distribution system through centralized controls at the power house and reduce basic losses in the system components.

More fuel efficient engines are available and fuel efficiency should be a high priority when replacing existing engines or adding capacity. The NUC generators are aged and in poor condition, as indicated by the high level of de-rating of all the units. The average fuel efficiency of the diesel generators is 3.3 kWh/litre, which is significantly lower than the Pacific average of 3.8 kWh/litre (PPA, 2012).

Non-technical losses in NUA are considered excessive and need to be addressed by management but though a reduction of those losses will provide benefits with regards to the tariff that needs to be set to break even, it will have little or no effect on the quantity of fuel used per kWh generated.

Table 8 - Summary of initial supply-side energy efficiency opportunities

Area	Item	Description
Unbilled usage	Street lights	Replace existing street lights with energy efficient street lights, bill communities or GoN for street lighting, investigate and stop electricity theft.
Non-technical losses other than unbilled usage	Unpaid or extraordinarily late payments of bills	Install prepaid meters for all customers on standard meters who are not paying bills on time.
Technical losses	Distribution system	A general survey of the existing distribution system should be carried out and, if shown to be economically reasonable, a plan prepared for upgrading.
Technical losses	Generation	Selection of more fuel efficient engines when replacing existing engines or adding capacity

5.2 Experience with supply side energy efficiency

In general, supply side efficiency improvements have been found to have a longer life and more predictable results than those attempted on the demand side. With supply side efficiency actions, the utility has full control over the improvements and their maintenance and has specialized staff available to install and maintain the gains in efficiency provided by the improvements. Demand side improvements require significant actions by a large and diverse group of customers who all must have the persistence and skills needed to maintain the gains made, else the efficiency initially gained will be slowly lost over time.

After the sudden fuel price spike of 2008, the managements of most Pacific utilities have become increasingly interested in pursuing supply side efficiency improvements. For a number of years, the Pacific Utilities have been supported by the Pacific Power Association (PPA) through the provision of the training and technical support needed to improve supply side efficiency.

NUC has made significant progress over the past 10 years in improving generation efficiency and as shown by the 2012 PPA study has a level of technical losses that is comparable to that of other Pacific utilities of a similar size – though improvement is certainly still possible. A programme of repairs and equipment replacement for the distribution network has commenced with funding from the EU although there is still a lot of work to be completed. Overall fuel use per kWh delivered to customers probably could be reduced a few per cent without engine replacements. As that reduction in losses will affect every kWh generated, the savings provided by even a few per cent in supply side efficiency improvements will be substantial.

5.3 Challenges for implementation of supply side energy efficiency

The primary challenge for implementation of supply side energy efficiency measures appears to be access to funds for the needed capital investments and management of contracts to bring in overseas contractors to carry out much of the maintenance, repair and replacement work.

In general it is clear that NUC management has a good understanding of how to improve supply side efficiency but does not have access to the funds and human resources needed to carry out the actions. In recent years, funds from development partners have focussed on renewable energy infrastructure, rather than traditional power generation. However, benefits from supply side energy efficiency should be highlighted where they are cost-effective and put forward for support alongside renewable and demand side energy efficiency.

6 Demand Side Energy Efficiency

6.1 Demand side energy efficiency opportunities

Decades of very low (or no) electricity costs for energy consumers has resulted in a much higher per-capita energy usage than is seen in most island countries (SPREP, 2005). In a general sense, it can therefore be expected that there are many opportunities for demand side energy efficiency improvements, particularly in the residential and government sectors. However, until there is a better understanding of the actual energy use patterns and the energy using equipment's characteristics, well targeted programmes to help electricity consumers reduce energy cannot be confidently prepared. Surveys (household and businesses) and audits where appropriate should precede the design of programmes for demand side management (DSM).

6.2 Experience with demand side energy efficiency

From 2007 to 2010 various demand-side activities were undertaken in Nauru under the auspices of the REP-5 project, funded by the European Union. These included in 2009 the installation of over 1800 pre-payment meters in homes and businesses. A demand-side energy efficiency action plan was also drafted and two energy efficiency officers were hired. The two officers carried out an awareness campaign on energy efficiency and conservation that targeted homes and small businesses. This included school and community energy efficiency competitions. However, after the end of the project in 2010, the energy efficiency officer contracts were not renewed and the campaigns were not sustained. This shows that the long-term continuous measures typically required for successful DSM cannot be dependent only on external short-term project funding.

A major driver of demand side energy efficiency is the energy price. So long as energy costs remain artificially low, as has long been the case in Nauru, programmes to improve demand side efficiency have tended to have only a short term effect with energy usage soon rising back to pre-programme levels after the programme concludes. For demand side energy efficiency programmes to have the longest lasting benefit, the energy using hardware needs to be upgraded with low maintenance, long lived, high efficiency equipment (e.g. replacement of standard fluorescent fixtures with long-life high efficiency LED units) and it is best if consumers expect substantial price hikes for energy in the future (e.g. a well publicized government plan to gradually reduce subsidies on electricity).

6.3 Challenges for implementation of demand side energy efficiency

Demand side energy efficiency improvements in residences probably can do more to reduce fuel imports than any other energy efficiency action. However, residential DSM is also the hardest to implement and to maintain so long as electricity tariffs are heavily subsidized. To implement and maintain energy efficiency actions in the residential sector will require constant interaction with communities explaining why DSM is important to them and to Nauru and for educating individual households as to how to lower their electricity usage without any loss of quality of life. Since supporting investment in energy efficiency measures is less costly over the long term than the current subsidies to electricity customers, it makes good sense for

Government to work with donors and internally to provide incentives to households to install more efficient lighting and appliances and to improve their homes in ways that reduce the need for fans and air-conditioning. To design effective incentives, a good knowledge of how households in Nauru use electrical energy is needed as well as a good knowledge of the characteristics of the energy using equipment in households.

Because of the tendency for households to slowly drift back to lower energy efficiency patterns, so long as electricity tariffs are kept artificially low, customers will need to be constantly reminded of the need for staying energy efficient and measures will need to be taken to encourage households to purchase high efficiency lights and appliances rather than the normally lower initial cost, lower efficiency devices.

7 Data collection needs

7.1 Data collection relating to the Nauru energy balance

In order to monitor progress toward Nauru's energy sector goals and to plan for future energy projects, it is essential that accurate, timely, (reasonably) complete, consistent, up-to-date and accessible data be collected, stored and maintained regarding renewable energy resources, energy imports and energy use in Nauru.

7.1.1 Energy import data

Imported energy for Nauru means fossil fuel imports. Unambiguous records of the quantity of fuel imports, their timing and the specific type of fuel imported are vital to the determination of the Nauru energy balance. These data should be quantity based, not value based, and should accurately reflect the timing and type of energy that is imported to Nauru, its source and its storage location.

7.1.2 Energy Use Data

Fossil fuel usage for land transport, sea transport and air transport should be accurately collected along with the patterns of usage of energy for each type of transport. These data then can be used to help determine opportunities for energy efficiency improvements and for replacement of imported fossil fuels with renewable energy. For example, if a major use of imported fuel is for land transport, analysis of the use patterns can indicate if electric vehicles charged by renewable energy may be attractive, if incentives for car pooling are likely to work or if mass transport systems can be expected to reduce transport energy use.

Fossil fuel use for electricity generation and the pattern of electricity usage are essential data for the formulation of programmes for supply side and demand side energy efficiency programmes. High-resolution load data are also necessary for accurate grid stability modelling. Diurnal electricity load patterns, load patterns on different days of the week are also very important data needed for the analysis of the ability of solar and wind energy inputs to offset fossil fuels for electricity generation. Collection and analysis of energy use data relating to both quantity of energy used what the energy is used for and the time of day of the energy use is necessary for the preparation of comprehensive and effective DSM programmes.

Data regarding the electricity generation, transport and other activities that affect the national energy balance and are provided by renewable energy must also be collected in order to determine the overall percentage of total energy use that is provided by renewable energy. As new renewable energy projects are installed, the energy they provide and information on the use made of it should be collected in order to enable monitoring of progress towards Nauru's renewable energy targets and planning of future renewable energy projects.

7.2 Data collection for Renewable Energy Implementation

In order to be able to design renewable energy systems and predict their performance, a good understanding of the renewable energy resource is required. Because many renewable resources, such as wind, solar energy and wave energy, vary in multi-year cycles, it is important to maintain long term data collection for all renewable energy sources in use and expected to be used in the future. There is currently collection of some solar resource data on Nauru. However, after the first year of installation, the wind resource monitoring equipment was damaged and the reliability of the data it is collecting is questionable. There are no other resource monitoring programmes currently underway.

For optimal integration of renewable energy in the electricity mix, good quality, detailed data are necessary to conduct a grid stability study and identify the most cost-effective improvement actions (i.e. controls, dispatching strategies, deferrable loads, etc.).

7.3 Data collection for preparing energy efficiency programmes

Given that the primary data needed for supply side energy efficiency improvements were determined through the PPA funded NUC study in 2012, energy efficiency data collection needs to concentrate on the demand side.

7.3.1 Residential energy use data requirements

The use of prepaid meters with their random timing for energy purchases makes it more complicated to determine periodic energy use by NUC residential customers. Although monthly meter readings are no longer made, there remains a need for NUC to make use of software that can synthesize monthly energy usage for individual customers in order to determine actual patterns of household and small business energy use. This is needed both to provide a baseline for the monitoring and evaluation of energy efficiency efforts and for classifying customers into usage groups to aid in delivery of the appropriate energy efficiency programmes. If not already available in Nauru, this software will need to be obtained through the supplier of the prepayment meters.

To develop effective, properly targeted energy efficiency programmes, a detailed survey of household and small business energy use will be needed. The survey should include a detailed inventory of the energy using devices that are in use, their power requirements, their age and conditions and their typical period of usage per day/week. For sites using air-conditioning, details of the building and its characteristics also need to be included.

7.3.2 Commercial/Industrial DSM data requirements

For all commercial facilities other than RONPHOS, energy use is largely confined to office machines, lighting, refrigeration and air-conditioning. Energy audits focusing on these areas in the buildings occupied by the commercial entities should be adequate to provide the data needed to develop energy efficiency programmes for that sector. As with residential audits, construction characteristics of the buildings that include air-conditioning should be included in the audits.

For RONPHOS, energy audits of the type to be used in the commercial sector will be appropriate for office and warehousing buildings but specialized audits will be needed for gathering data on the phosphate processing and handling energy use.

7.3.3 Government Buildings DSM data requirements

For all government buildings, detailed energy audits and data regarding building construction characteristics will need to be carried out. Where government buildings are not on prepayment meters, monthly meter reading should take place to record electricity usage.

7.3.4 Water Supply DSM data requirements

Since roughly 20% of electrical energy supplied by NUC is used for water desalination, a detailed audit of the entire water system from connection to the grid through end use will be an important part of the data gathering requirement for developing actions to improve demand side energy efficiency and to prepare a baseline for measuring the effect of those actions.

A first step in this process would be to install individual electricity meters on each of the reverse osmosis (RO) machines as well as record daily production of water from each individual machine. With the recent installation of a new RO machine, these means daily monitoring of three RO machines for electricity consumption and water production.

7.3.5 Transport data requirements

A general survey of the vehicles and boats in Nauru and of their patterns of use is needed to properly design energy efficiency improvement programmes for Nauru transport and investigate renewable energy options. In particular, patterns of use of personal vehicles, including motorcycles which are increasingly being used on Nauru, and bicycles, need to be better understood. This would enable the design of appropriate energy efficiency measures, such as mass transit or transport sharing programmes and the investigation of options for renewable energy use such as electric vehicles charged through solar stations.

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Annex 1 – Indicative list of energy sector investments in Nauru 2004 – 2017

Programme / Project	Funding	Executing Agency	US $m	Start (est.)	Finish (est.)	Other comments
Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project (PIGGAREP)	GEF	UNDP/ SPREP/ NUC	0.06	2007	2013	Inception workshop November 2007. Budget of 5.2m split by 12 (11 countries and management cost). A total of approx. 60,000 USD has been allocated for Nauru with 47,920 USD spent by end 2012 on solar and wind technical assistance projects (PIGGAREP, 2012).
Low Carbon Islands Programme	GEF	UNEP/ IUCN	0.50	2013	2015	Inception workshop May 2013. Budget of 1.5m for 3 countries (Nauru, Niue and Tuvalu).
PEC Commitment - 132kWp solar plant (accompanying a reverse osmosis desalination plant)	Japan	PIFS	1.32	2012	2014	Implementation of the Pacific Environment Community (PEC) Commitment. Budget of 66m split between 14 countries. Nauru project expected to save 60 tonnes of diesel per year, contributing to 1.3% of the current energy demand. Funding for solar
Strengthening Capacity of Pacific Developing Member Countries to Respond to Climate Change	ADB	ADB	0.22	2009		Estimated budget of 3.1 million split between 14 countries.
Capacity Support for Sustainable Management of Energy Resources in the Pacific Region	EU	PPA	0.11	2009	2012	Estimated budget of 1.6m split between 14 countries.
Capacity Support for Solar PV Stand Alone & Grid Connected Systems and Demand-side	EU	PPA	0.04	2009	2012	Estimated budget of 0.6m split between 14 countries.
Support to the Energy Sector in Five pacific Island Countries - Nauru EDF-9 national allocation -	EU	IT Power / Nauru govt	2.50	2007	2010	EDF9 national budget allocation focus was on grid-connected solar PV, prepayment meters and demand side energy efficiency (IT Power, 2009)
Clean and Affordable Energy for the Pacific Islands	AusAID	PRIF and others	1.50	2009	2012	Estimated budget of 22million split between 14 countries. Difficult to avoid double counting as this is implemented by various organisations.
Renewable Energy & Energy Efficiency Partnership (REEEP) Pacific Programme	Australia	REEEP	0.09	2007	2012	Estimated budget of 1.3 million split between 14 countries but unclear if Nauru benefitted from these funds as allocation was via a competitive call for proposals.
Solar Home Systems	Taiwan	Nauru govt	0.10	2009	2009	Installed at homes but some are also at churches. 7.8 kWp in total (60 SHS at 130 Wp each).
Solar Street Lights	Taiwan	Nauru govt	0.30	2011	2011	155 units installed, 130W each. Many already not working.
Coping with Climate Change in the Pacific Island Region (CCCPIR)	Germany	SPC/GIZ	0.05	2012	2014	Technical assistance only, no hardware. Budget of 1m split between 14 countries. Approximately 50,000 USD allocated to Nauru.
30 kWp Grid-connected solar PV installation on Government building	Taiwan	Taiwan	0.15	2012	2012	Funding estimated based on cost of 5000 USD/kWp.
EDF-10 national energy assistance - Renewable Energy and Energy Efficiency Programme	EU	Nauru govt	2.60	2010	2014	EDF10 national allocation funding with focus on grid imrovement for renewables integration, energy efficiency and institutional support of the NUC.
Nauru Infrastructure Reform Support for NUC	Australia	AusAID	60.00	2004	2017	Support for urgent generation and distribution system projects. The support includes the provision of fuel (4-5m per year) and supplementary managerial staff, technical assistance and physical investments.
Regulatory Reform for improving water and electricity supply in	ADB	ADB	0.20	2010	2013	Ongoing technical assistance.
Nauru Pacific Adaptation to Climate Change (PACC) Demonstration Project – Solar Water Purifiers	GEF	UNDP/ SPREP/ CIE	0.08	2011	2012	Demonstration project targeting the water sector and delivered by the Pacific Adaptation to Cliamte Change (PACC) project. 20 solar water purifying units with 4 panels per unit were installed in two districts.
Solar water pumps	Japan	JICA	0.00	2010		160W pumps. Timing of installations estimated, amount of funding provided and number of solar water pumps unknown.
Solar LED handheld lights distributed to households	Taiwan	Taiwan	0.00	2011		Timing of distribution estimated. Amount of funding and exact number of units distributed unknown.
CFLs distributed to all households	Taiwan	Taiwan	0.60	2012	2013	Timing of distribution estimated. Number of units distributed unknown.
Technical assistance for tendering of the tank farm management and operations	PIFS	PIFS / SPC	0.10	2011	2012	Estimated value of technical assistance in person-months. No contract was concluded following the tender process.
Technical assistance and support for capacity building from SPC in the energy sector	Various	SPC	0.05			Estimated value of technical assistance in person-months and value of travel budget provided for Government of Nauru officials for the two year period 2011-2012 (Source: SPC EDD Annual Report, 2011 & 2012)
Government of Japan - Non Project grant Aid (NPGA)	Japan	Nauru govt	5.00	2009	2013	Approximately 1 million AUD per annum has been provided for the pruchse of petroleum imports for the last 4-5 years (Source: CIE, 2013)
Pacific Islands Renewable Energy Project (PIREP)	GEF	UNDP / SPREP	0.04	2003	2006	Regional project of total value 700,000 AUD. Exchange at June 2013 values used to convert to USD. Assumed equal split between 14 PICs) (PIFS, 2013)
Pacific Islands Energy Policy and Strategic Action Planning (PIEPSAP) project	Denmark	SOPAC	0.14	2004	2008	Regional project of total value 1.6m Eur. Exchane rate at June 2013 used to convert to USD. Assumed equal distribution amongst 14 PICs (PIFS, 2013)
Grant Assistance for Grassroots Human Security Project (GGP)	Japan	CIE	0.10	2013	2014	The GGP project for 2013-2014 will be solar water purifiers (PIFS, 2013)
Nauru Third National Communication project	GEF	UNDP / CIE	0.25	2013	2016	Mitigation allocation (50% total funds) (PIFS, 2013).
Environment Resources Adviser for CIE	Australia	CIE	0.15	2012	2014	Mitigation allocation (50% total funds) (PIFS, 2013).
Energy Efficeincy Programme for Nauru - EDF10 regional allocation	EU/ADB	ADB	3.00	2014	2016	Will support actions in supply side energy efficiency. No further details available at this time.
	TOTAL million USD		**79.25**			

Annex 2 – OTEC Thermal Energy Conversion in Nauru

A Note on Ocean Thermal Energy Conversion (OTEC) in Nauru [15]

In 1981 and 1982, the Tokyo Electric Power Company (TEPCO) in association with Toshiba of Japan installed and began technical trials of a mini-OTEC facility on the west coast of Nauru on the shore across from the current location of the Civic Centre in Aiwo. The facility had a gross power continuous rating of 100 kW and was expected to provide a net power of around 14.9 kW. The design was of the closed cycle low pressure turbine type and used Freon 22 as the working fluid. Very expensive titanium heat exchangers were used to provide high efficiency heat exchange for the low temperature differences used in the plant.

The design used a 27.8 kW peak rated pump to bring 0.395 m^3/s of warm 29.8° surface water into the facility on the hot side. For the cold (deep water) side, a 43.3 kW peak rated pump brought water at 7ºC from 580 metres deep through a 945 metre long 700 mm diameter polyethylene inlet pipe at a flow rate of 0.382 m^3/s. A Freon pump rated at 15.3 kW peak circulated the Freon working fluid at 74 tonnes/hour and a 2.5 kW pump provided high pressure oil for the bearings of the 3000 rpm axial flow turbine. Although intended for 100kW continuous operation, the system flows could be increased to provide a maximum of 120 kW gross which then provided a maximum net power of 31.5 kW.

At the time, the Nauru installation was the first land based OTEC plant in the world to produce net power, it was also the highest power OTEC plant ever operational and the first (and last) to feed power to an operating commercial grid. It was known that it would not be a cost effective power supply for Nauru when it was installed and the system was not intended as a permanent installation but only a technical trial; it actually operated as a power generator feeding the Nauru grid for only 240 hours (a record for OTEC at the time, the US funded, barge mounted floating 50 kW Hawaii mini-OTEC built about the same time ran only 110 hours). The actual cost is not available but estimates go higher than US$1 million, all paid by TEPCO and Toshiba.

Since that early installation, there have been significant improvements in high efficiency low temperature heat exchanger designs eliminating the need for the use of very expensive titanium metal. Additionally, an open cycle OTEC design has been successfully operated in Hawaii. That design would be of particular interest to Nauru since a side benefit is the production of large amounts of fresh water. Also, the large volume of nutrient rich 7º C water from the deep water intake could be used for district air conditioning and cold water aquaculture thereby possibly providing significant additional side benefits.

With the very rapid drop-off that occurs beyond the reef in Nauru, there is an opportunity for OTEC energy development once engineering and commercial trials are completed elsewhere. However, the 1981-82 installation in Nauru remains the only OTEC facility that has actually delivered power to a public grid. Several engineering trials have been attempted, up to 1 MW of gross power capacity, but no plants have yet to be built that are suitable for utility use and it does not appear likely that OTEC can be a part of the Nauru energy economy within the next 10 years, since there still are no OTEC plants anywhere in the world currently producing electricity. Even if the go-ahead for utility scale trials were to occur today, it would be at least five years before an operational, utility scale plant would be commissioned and another five years should be allowed to work out the problems and to determine the real costs that such a plant has for O&M.

[15] Details of the Nauru OTEC trials are from the PIREP Report for Nauru: Wade, Herbert, Pacific Regional Energy Assessment 2004, Vol. 7 Nauru National Report, SPREP 2005.