# FEASIBILITY OF GRID-CONNECTED WIND POWER FOR RAROTONGA, COOK ISLANDS – DRAFT REPORT

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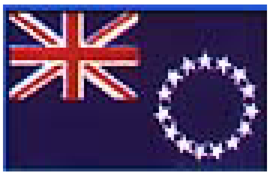
**~ Participating Pacific Islands Countries ~**

***Cook Islands***, *Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu*



# Feasibility of Grid-Connected Wind Power for Rarotonga, Cook Islands

## Draft Report

March 2006

*Prepared by:*
Gerhard Zieroth, Manager PIEPSAP

This report is based on two documents: The Project Proposal for Grid Connected Wind Power on Rarotonga presented by UNDP Samoa in March 2002 and the Evaluation of Grid-Connected Wind Electric Power Project Proposals for Rarotonga, Cook Islands, by Chris Cheatham and Gerhard Zieroth commissioned by UNESCAP Bangkok, August 2002.

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# Executive Summary

The Cook Islands energy sector relies 100 % on imported fuels for transport, electricity generation and household use. In the year 2005 the world has experienced a period of price volatility for petroleum that saw petroleum prices increase from US$ 40/bbl in mid March to US$ 70bbl in September. At present wind energy is considered to be the most attractive renewable energy source for grid connected electricity supply in the Cook Islands. For the Rarotonga system, wind energy penetration up to a maximum of 30% seems to be manageable without jeopardizing system stability and security. The significant benefits of such a project include the displacement of diesel power generation and consequent fuel and other operating savings, which are quantifiable, and the diversification of energy sources for power generation in Rarotonga and increased security of supply from a reduced dependence on foreign supplies of fuel. The later benefits are not quantifiable, however, fuel price developments of 2005 have demonstrated the high degree of vulnerability of the CI economy.

CI has been able to gain some experiences with wind technology in the Mangaia project funded under the PREFACE[1] project. While this project enabled the operator of two 20 KW Vergnet generators to accumulate practical experience a number of problems were encountered including mechanical failures of the wind generators installed, equipment corrosion, system integration and communication problems. Perhaps the most serious problem is a mismatch of demand and supply that at present cannot be managed through storage. Consequently, fuel savings fall significantly short of the predictions of the feasibility study resulting in a poor economic performance. It is important to note that the experiences of this project cannot be generalised and deemed to exemplify the performance of wind generation in small systems. An analysis of the project shows serious shortcomings in planning preparation and design of the project. When properly planned and implemented wind generation can be successfully integrated into small systems as a number of projects around the world have demonstrated.

However, wind energy development - even when planned and implemented in line with international practices – will involve certain risks that need to be managed effectively in order to ensure a successful project outcome for the CI Government, the power utility TAU and the electricity consumers. Uncertainty about the wind regime at possible sites for grid connected wind farms need to be addressed through wind data collection, processing and modelling of wind farm output. Technological risks could be allocated to an experienced IPP developer through a BOOT procurement procedure or could be mitigated through a capacity building program that would enable TAU to acquire the skills and knowledge necessary to successfully operate a wind farm. Risk of hurricane damage could be mitigated through adequate design and specifications for the generators to be installed. The guiding principle of risk allocation should be that the party that is best able to minimise, manage, control or bear the risk or is the party that receives the greater economic benefit of running the risk should take it. Under international competitive bidding, TAU could determine what energy tariffs competitors would be able to offer and test them against their own projected generation cost at an assumed diesel price. TAU would take the risk of being locked into a long term power purchase agreement (PPA), and would be at a disadvantage if diesel costs turned out to be lower than anticipated over the long term. On the other hand, lower than expected diesel fuel prices would—at constant

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[1] (Pacific Regional rural Energy France Australia Common Endeavour)

consumer tariffs—certainly not jeopardize TAU's financial position and wind energy could still be regarded as an insurance against fuel cost fluctuations.

The wind project proposals for Rarotonga that is considered in this report has originally been prepared by UNDP/UNESCO with assistance from the Danish NGO 'Forum for Energy and Development' in consortium with a Danish wind energy developer. The technical design of the original Danish proposal had been based on a configuration of 8x225 kW Vestas turbines.

This may not be the optimal solution and alternatives that are discussed in this report should be tested through an international competitive bidding process. The update of the economic and financial evaluation based on current fuel supply cost and state of the art technology confirms that a wind farm in the 2 MW range is an attractive project, that offers sufficient return to be either pursued as an IPP investment or as TAU's own project. International environment-related grant aid assistance may further improve the economics of the project.

## Main Conclusions and Recommendations

- A grid-connected wind energy project for Rarotonga in the 2 MW class is technically feasible and financially and economically sound at current fuel price levels. A conservative base case calculation of the projects Economic Internal rate of return shows a value of 4.4 %. This result assumes constant fuel supply cost of 1.02 NZ$ over the project period of 20 years. If a 3 % increase in fuel prices is assumed the EIRR improves to 7.8%. Carbon credits at NZ$ 30 per ton of $CO_2$ saved will improve the base EIRR to 5.74%. If at the same time investment cost can be reduced by 20 % an international environmental grant (the EU energy facility would be a potential source) the EIRR would reach 11.8 %. This would clearly bring the project in a range that is attractive to the Government of the Cook Islands and TAU.

- The Government in consultations with TAU should now decide if it wants to pursue the wind project. In order to proceed with further project preparation, securing the site (or the sites) in consultation with landowners and local residents should be the next step. Compensation - if any - should be made contingent of the wind energy project actually going ahead.

- The wind resource at the secured site in Rarotonga should be closely monitored over a period of at least 12 months, beginning as soon as possible.[2] Monitoring should be at a site that has been secured in consultation with landowners. Funding for such a wind-monitoring project has been earmarked under PIEPSAP.

- Familiarization of appropriate officials in the Cook Islands, from both the government and TAU, by direct observation of a state of the art wind energy project that is similar to that proposed, such as the one operating at King Island, Australia by means of an in-depth study tour is highly recommended. Support for the study tour could be arranged through technical assistance.

- There are two basic options to finance the project: (i) a direct investment by TAU or the Cook Islands government, or (ii) a private sector-financed

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[2] UNDP in co-operation with SOPAC is currently implementing wind data collection project on the preferred wind site

investment under a Build-Own-Operate or Build-Operate-Transfer or similar arrangement. Both options have pro and cons that the government has to weigh. We recommend option (ii), as a direct public sector investment would shift significant risks to the government.

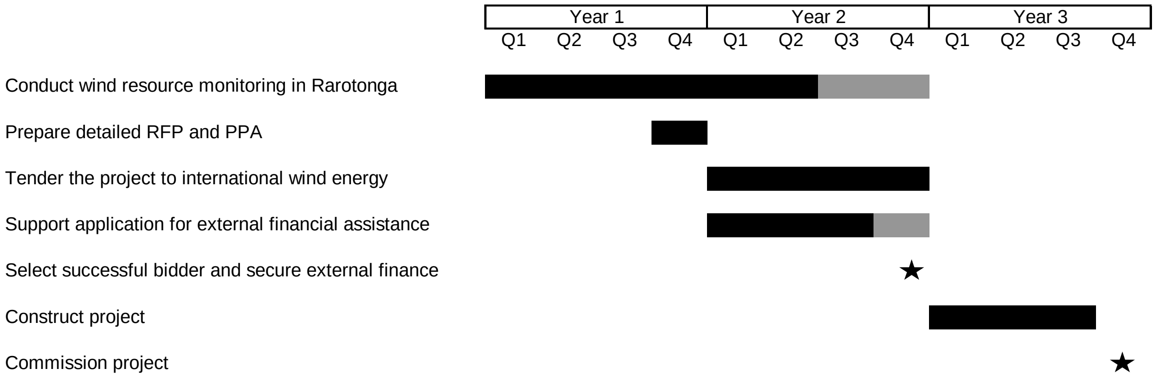
- The private sector developer would be responsible for applying for external environment-related assistance, but the government must assist that process as far as possible with the provision of information and appropriate project preparation prior to requesting proposals from international wind project developers, and actively support the application process after a developer is selected.

- Twelve months would be required for the tendering process, to allow bidders to assess site conditions (including the wind regime) carefully and affirm estimates of project performance. As tendering will commence after the wind resource monitoring is well underway, a total project period (covering commencement of wind monitoring through commissioning of the wind project) of up to three years should be allowed.

- It is recommended that technical assistance to the government of the Cook Islands be arranged to develop an appropriate Request for Proposals (RFP) and draft Power Purchase Agreement (PPA) for negotiation with the successful bidder. Alternatively bidding documents for an engineer, supply construct contract (EPC) including a management period of at least 5 years cold be developed. The TA might be arranged through PIEPSAP, the World Bank’s Private Participation in Infrastructure Advisory Facility (PPIAF) or a similar program.

- It is recommended that the wind project developer - or as the case may be the supplier/management contractor - be selected through an international competitive bidding process. In case of an IPP the winning bid would be selected on the bases of the offered selling price of electricity from the wind project to the Rarotonga power system and the financial soundness and corporate background of the developer. The bid price and the financial soundness of the developer will provide market-proven indicators of the economic viability of grid-connected wind energy in Rarotonga.

- We suggest the following ‘timeline’ for implementation of a wind energy project in Rarotonga over 30-36 months:



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# 1.0 Introduction

The government of the Cook Islands has requested assistance from PIEPSAP to support its efforts to improve energy planning, diversify the Cook Islands energy supply, implement energy conservation measures and increase energy security through the development of indigenous energy resources. At a National Energy Planning Workshop[3] held in Rarotonga on October 20, 2005 it was agreed amongst key stakeholders to respond to the severe energy cost inflation with an action plan that defines a program of concrete activities all aimed at lowering the countries vulnerability. Following the guidance provided by the Deputy Prime Minister at this workshop, the Cook Island Energy Action Plan (CIEAP) that was developed describes measures to be taken, allocates responsibilities and defines indicators that allow the monitoring of progress and impact of the CIEAP. The CIEAP is designed as a multi-stakeholder initiative. It aims to produce tangible benefits for the economy that include cost savings, reduced greenhouse gas emissions and pollution, and improved energy security. A copy of the CIEAP is attached to this report as Annex 2.

In their 2005 workshop, the stakeholders agreed that one of the priority components of CIEAP would be to update technical and economic evaluation of a wind energy proposal that was submitted to the government through UNDP in 2002. Back in 2002 an independent evaluation of the proposal showed that at fuel supply cost prevailing then the proposal to construct a grid-connected wind energy system on the main island of Rarotonga was economically and financially marginal. It would have only be a sensible option if an aid package could have been provided to render the project viable from TAU's and the CI Government's perspectives. As a consequence the project was not pursued. Unfortunately, the recommendation of the evaluation to embark upon a measuring program to improve wind data for Rarotonga was not implemented. This implies that though the results of the present study are significantly different from those presented in 2002, the accuracy level of the results remains unchanged.

Workshop participants at the 2005 CIEAP workshop discussing the up-date of the study on wind power for the Rarotonga system.

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[3] A list of workshop participants is attached to this document as Annex 1D

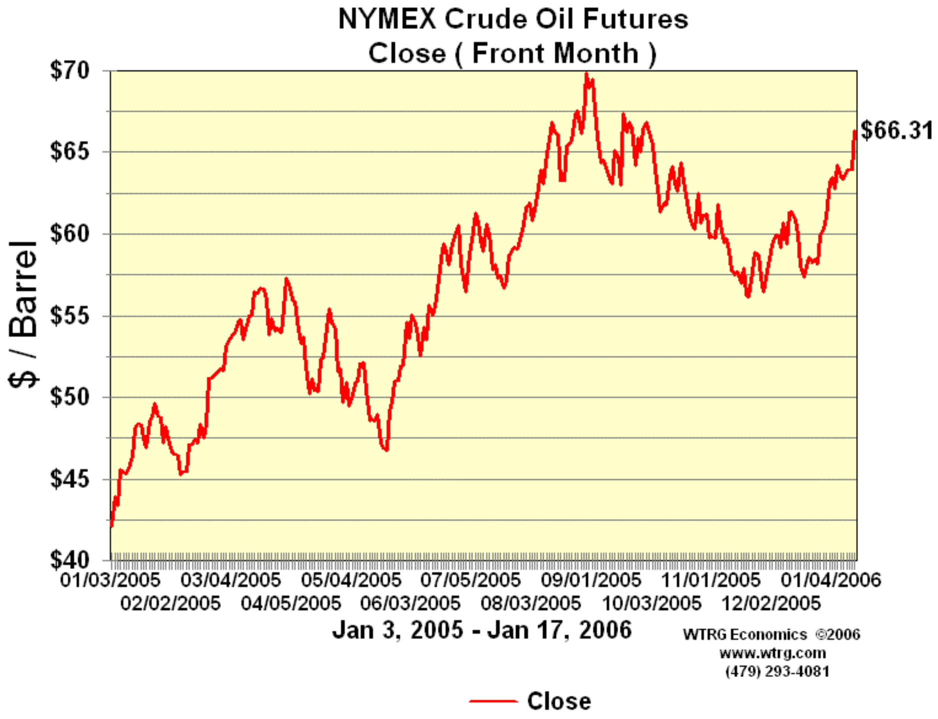
## 2.0 The Cook Island Energy Sector

### *2.1 Reliance on Imported Fuels*

The Cook Islands energy sector relies 100 % on imported fuels for transport, electricity generation and household use. Imports were 23 million litres in 2004 of which diesel accounted for the lions share of 12 million litres, gasoline 5 million and multipurpose kerosene 7 million. Rarotonga typically consumes 90 % of the fuel imports, Aitutaki follows with approx 7 %. The other islands share the remaining 3 %.

In the year 2005 the world has experienced a period of price volatility for petroleum that saw petroleum prices increase from US$ 40/bbl in mid March to US$ 70bbl in September. The graph below represents the move of crude oil futures in 2005. This international development has been reflected in local fuel and electricity price increases. More than ever, fuel imports are a major component of the country’s import bill. At the same time affordable, stable and secure sources of energy are vital for Cook Islands future economic growth and prosperity and it is Government policy to reduce the country’s vulnerability to external forces.

**Chart 1: Crude Oil Price 2005**



Source:http://www.wtrg.com/daily/crudeoilprice.html

Three multinational oil companies supply fuel to the three oil terminals located in Rarotonga. Outer islands are supplied from Rarotonga in 200 liter drums. Aitutaki is supplied directly from NZ by the Reef company using 20 ton bulk liquid ISO containers (tanktainers). Fuel prices for motor gasoline and diesel have traditionally been regulated in Cook Islands using a pricing template. The regulation only covers the quantities sold to the general public, in Rarotonga, i.e. the volume consumed for power generation and the fuel supplied through Reef to Aitutaki is not included into the regulation. It is interesting to note that retail prices in Aitutaki have been competitive with those in Rarotonga although supply cost were significantly higher.

In 2005 an independent consultant reviewed the CI fuel pricing template and its application as a regulatory tool. The review came to the conclusion that significant price reductions could be achieved for the consumers. The report states:

*"It is estimated that the value of fuel price reductions available through direct negotiation with oil companies is in the region of NZ 12-33 cents per litre. For this to be achieved, however, Cook Island negotiators must be supported by strong political will. Additional savings beyond this are potentially available through the optimization of local fuel import logistics, a course of action that we will also strongly recommend."*

Even if the CI Government achieves price savings through the implementation of the recommendations, development of world market prices will certainly remain out of the Governments control. Although energy price developments are notoriously difficult to predict we assume for the purpose of this report that prices below 50 US$ a barrel of crude oil are unlikely to return. Also it appears to be save to assume that price volatility will continue, as the political situation in the Middle East remains unstable.

Energy Conservation Transport Cook Islands Specific Fuel Consumption per 100 Km

As high reliance on imported fuel and exposure to price shocks will remain a problem for the Cook Islands. However, there are three options to cushion the negative impacts to the Cook Island economy: Firstly, the Government can keep the margins of the oil suppliers at acceptable levels through competition and the application of regulation using a transparent and fair pricing template. Secondly, there is significant potential for energy conservation in both the electricity and the liquid fuel sectors.

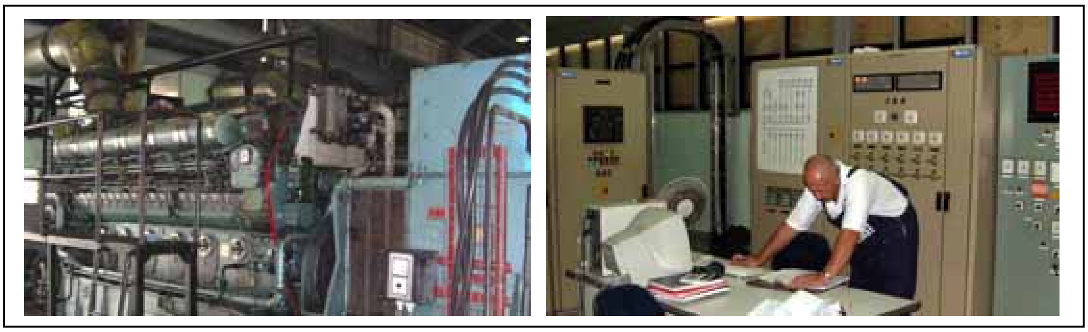
Thirdly, the development of indigenous energy resources such as wind and biomass offers the potential to reduce consumption of imported fossil fuels. The CIEAP cites the development of a wind energy project on Rarotonga and the possibility to develop biofuels for outer islands as options to be pursued. In the past the wind project for Rarotonga has already attracted considerable interest amongst private sector developers.

### 2.2 Electricity Supply in Rarotonga

Power supply in Rarotonga is the responsibility of the Rarotonga Electricity Authority. (TAU). The operation of the government owned utility is governed by the TAU act of 1991 and its amendment of 1999. TAU essentially consists of a generation and a network division supported by finance, audit and customer services. It employed a total of 41 staff in 2005. TAU owns 74 km of 11 KV and 190 Km of low voltage lines. Its total assets in 2004/2005 were valued at 20.8 million NZ$. Revenue in this period was 11.4 million NZ$. TAU reported an operating profit of 1.11 million NZ$ for the same period. ROA fell to 5.3 % mainly due to unscheduled expenditure to repair cyclone damage and due to a 28 % increase in fuel supply cost.[4]

Rarotonga is fully electrified as the entire population lives in close proximity of TAU's 11 kV distribution network. In 2005, TAU served 3820 customers and generated 26.4 GWh in 6 diesel sets having a combined rated capacity of 7.6 MW. There was zero growth in electricity supply in 2005 that is explained by a general economic downturn as a result of the five cyclones that affected Cook Islands in this period. In order to cope with technical problems of some generator sets TAU also hired two 800 KW stand by sets. Peak demand was with 4573 KW at an all time high. Minimum demand was in the order of 2500 KW.

Plant availability in 2004/2005 was 83.20 % the lowest in three consecutive years. Also the Customer Average Interruption Duration deteriorated from 8 hours in the previous year to 15.6 hours. In 2006 an additional generator set having 2.5 MW capacity will be installed. This project is scheduled to be finished in August 2006 and will substantially increase TAU's generation capacity.



TAU generator and control room.

In the 2004/2005 financial year TAU used 6.7 million litres of diesel at a conversion efficiency of 0.253 l/KWh. This figure is in line with specific fuel consumptions in other utilities of similar size. With the installation of the new 2.5 MW set, SFC is expected to drop to 0.24 l/KWh.

Over the last ten years Electricity supply in the Rarotonga system has grown from 16.6 GWh in 1995 to 26.4 GWh in 2005. This represents an average growth rate of 4.7 %. In the absence of any indication of dramatic change this growth rate is assumed to apply for the next 10 years as well. I.e. for the year 2015, the Rarotonga system is assumed to require a supply of 43.74 GWh. As Peak load is expected to grow at the same rate to reach 7.2 MW in 2015.

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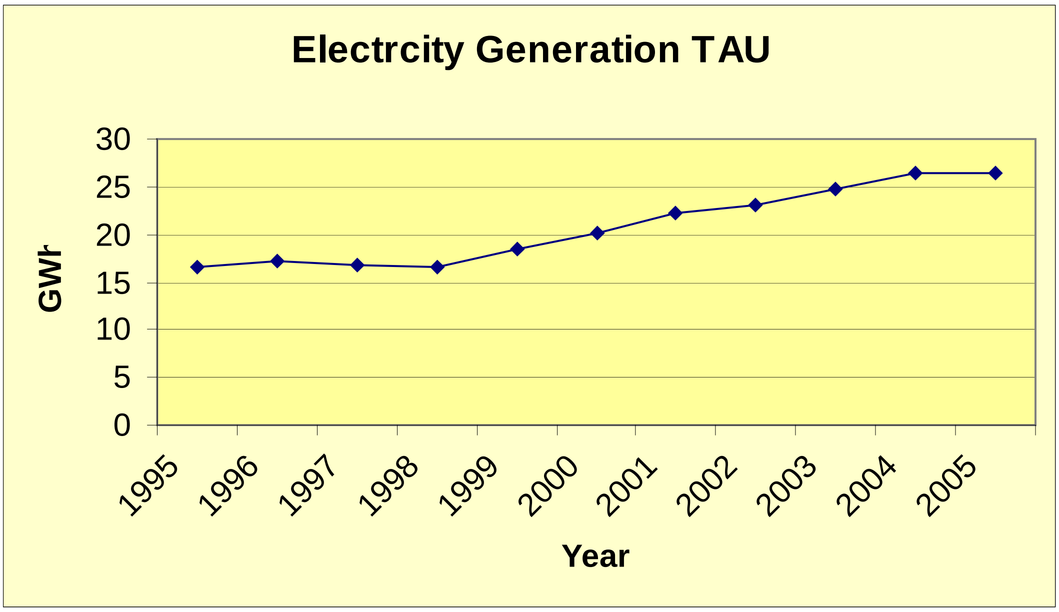
[4] TAU Annual Report July2004-June 2005

Growth in power supply over the last ten years is displayed in the Graph below.

**Chart 2: Growth Electricity Sales TAU**



It is interesting to note that demand growth from 2002 until 2005 remained within the band that was forecast in the 2001/2002 studies. The zero growth experienced in 2005 was essentially the result of an economic slow down in he wake of a destructive hurricane season and shows another aspect of the vulnerability of the Cook Islands economy.

# 3.0 Technical Analysis

## 3.1 *Wind Resources in Cook Islands*

For time scales extending from a month to a year, the ability to forecast wind speeds and the corresponding energy production has been developed to a high degree. In most cases the detailed energy production projections are based on site measurements for periods of 2 years or more if they form the basis for the financing, wind turbine siting, and construction of wind farms. Unfortunately, this type of data is not available for the Cook Island projects and forecasting energy output is therefore fraught with uncertainty and risk.

There are three wind data sources from the Cook Islands:

- Forum Secretariat (FSED) Wind and Solar Monitoring Project (hourly average wind speed and direction logging at 10 meters from 1 Jan 1995 – 31 Dec 1996) at Ngatangiia
- Long term average wind speeds from Raratonga Met Station/Airport
- SPC 10 min interval average wind speed and direction logging at 20 and 30 meters from 18 Apr 2001 – 9 Aug 2001 at Mangaia

The following table provides a summary of available wind data. It should be noted that wind monitoring is currently ongoing in Aitutaki, i.e. there will be additional data available to cross-check assumptions made for the Rarotonga site.

**Table 1: Wind regimes at various recording sites in Cook Islands**

| Site | Av Wind Speed (m/s) | Weilbull A | Weilbull K | Height meters ag | Altitude meters amsl |
|---|---|---|---|---|---|
| **Ngatangiia** | 5.5 | 6.26 | 2.26 | 10 | 3 |
| **Mangaia** | 6.7 | 8.56 | 2.6 | 30 | 110 |
| **Airport Raratonga** | 4.3 | - | - | 10 | 10 |
| **Ngatangiia adjusted** | 7.1 | | | | |

### Assumptions of the UNDP Proposal

In the period 1994-1996 Cook Islands participated in the Southern Pacific Wind and Solar Monitoring Project implemented by the Pacific Forum Secretariat. This project identified and measured wind (and solar) resources for grid connected wind power in five countries at latitudes south of 15° south (the four other islands where Viti Levu, Niue, Tongatapu and Efate). The measured wind speed for Rarotonga was the second highest of the five measurements and initial analysis proved wind energy to have potential on the main island. Using the data recorded in Ngatangiia the UNDP proposal assessed wind energy output of a hypothetical wind farm.

The UNDP proposal for a 1.8 MW wind farm was based on the actual hourly wind data from the Ngatangiia on Rarotonga. Measurements were linearly adjusted to an average annual wind speed of 7.1 m/s at 30 m height, thus reflecting the estimated wind resource at the site identified. For the assumed Vestas units this calculation yielded a gross output of 2,556 MWh per MW installed corresponding with a plant factor of 29 %[5]. Through multiplication into the standard power curve of the 225 kW wind turbines a correction factor of 0.87 was included in the calculations to make allowance for lower air density in this outline proposal, chosen as being representative for the proposed performance category. This represents a specific energy production of 2224 MW per MW installed (plant factor 25.4%).

The power production projection for the prospective wind energy site was calculated as follows:

The adjusted total annual hourly wind data set was binned in m/s bins and the number of hours per bin has been calculated by using the “FREQUENCY” function of Microsoft Excel. The binned data were multiplied into the net power curve for a typical, low wind version of a Danish made wind turbine in the 225-250 kW class, (adjusted to 87 percent for operational losses[6] and lower than standard air density on Rarotonga). This is a bin approach, without regard to time of occurrence.

The adjusted total annual hourly wind data set was replaced with the corresponding output reading from the net power curve of the selected wind turbine class, (again adjusted to 87 percent for operational losses), by using the “VLOOKUP” function of Microsoft Excel. The total sum of the output data was then calculated. This is a time of occurrence approach using each of the 8,760 hours of the year. Both calculations confirmed each other.

### Assumptions for the purpose of this study

One of the biggest challenges when considering wind is that its greatest benefits—such as the ability to generate power with minimal environmental impact—are not easily quantified and predicted. Although wind variations are not completely random, Rarotonga’s wind regime would result in intermittent supply of electricity. On time scales that are relevant to TAU’s power system operators, wind is statistically predictable in the same way that the electrical power demanded by the utility's customers is predictable.

The output of wind systems can be modelled as a negative load. The fact that wind has a significant non-random component implies that the wind can be forecast. The degree of accuracy depends on understanding the physical processes driving the wind, the accuracy of wind measurements, the capability of the modelling techniques employed and how far into the future the prediction extends[7]. Because of increased experience with wind generation and a large number of reference plants operated in a variety of climatic conditions, estimating future generation is possible with an acceptable degree of accuracy provided that on-site measurements supply a basis for modelling of future generation.

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[5] 29% of the time the plant is assumed to produce rated power output.

[6] An output reduction factor of 10 % was applied to the theoretical turbine output in the calculation of the projected annual energy production for the wind plant. This is in reflection of an empirical 1-2% turbine downtime, less than optimum airfoil cleanliness in periods of operation with low precipitation, scheduled turbine maintenance, partial obstruction of the available wind resource in certain wind directions, and any unforeseen interruption of the operation.

7 Forecasting the wind speed and duration for use in planning the next day's dispatch of utility generation resources, including wind systems, is an active area of research in the United States and Europe.

For the purpose of this study the original assumption of the UNDP study were corrected downwards by 10 %. This is based on the experiences made in New Caledonia. Plum is located at nearly the same latitude than Raratonga and should therefore have a similar, trade wind dominated wind regime. The UNDP Based on Based on gross energy of 4,600,000 kWh per annum, the plant factor of the Rarotonga project is 20% higher than the actual factor achieved in Plum, New Caledonia. In other words for the purpose of this study we assume a gross average annual wind supply from the Rarotonga wind farm to be 2,000 MWh per MW installed corresponding with a plant factor of 23%. (The wind energy project in Butoni, Fiji assumes a plant factor of only 13%). It should be noted that this figure would vary from year to year.

### *3.2 Wind Energy Experience in the Region*

Although still limited there is a growing body of wind energy experience in the region. There has also been considerable training in planning and appraisal of wind energy projects. It is assumed that a basis of knowledge about the technology is also present in the Cook Islands.

#### Cook Islands

CI has been able to gain first experiences with wind technology in the Mangaia wind installation funded under the PREFACE[8] project. While this project enabled the operator of two 20 KW Vergnet generators to accumulate practical experience, a number of problems were encountered including mechanical failures of the wind generators installed, equipment corrosion, as well as system integration, stability and communication problems. Perhaps the most serious problem is a mismatch of demand and supply that at present cannot be effectively managed. Consequently, fuel savings fall significantly short of the predictions of the feasibility study[9] resulting in a poor economic performance. It is important to note that the experiences of this project cannot be generalised and deemed to exemplify the performance of wind generation in small systems. An analysis of the project shows serious shortcomings in planning preparation and design of the project. When properly planned and implemented wind generation can be successfully integrated into small systems as a number of projects around the world have demonstrated.

An assessment of the Mangaia situation by SOPAC concludes: Through a lack of a thorough study of the power system in Mangaia in the feasibility study, the current system configuration is not optimal. This has lead to a number of problems:

- The wind resource is not used optimally because wind turbines are switched off too often.
- Wind turbines are often switched off because they cannot be controlled from a distance through communication problems.
- When the turbines are online, the required reactive power for their operation, is changing the reactive/capacitive balance of the system.
- The switching off of one of the reactors at the power house has made the load for the generators prevailing capacitive; this could lead to further stability problems.

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[8] (Pacific Regional rural Energy France Australia Common Endeavour)

[9] The feasibility study for the project was performed by the supplier of the equipment Vergnet of France.

There are a number of potential solutions for the stabilisation of the Mangaia power grid and SOPAC will assist the Cook Island Government in the rehabilitation of the project. Two SOPAC reports on the Mangaia project are attached to this document as Annnex 3.

### New Caledonia

New Caledonia has most wind energy experience in the region. There are four projects operational, two on the main island of Grande Terre, one in Lifou (10x60) KW, Ile des Pins (3x 60 KW). Two lessons can be learnt from the New Caledonia experience: Firstly, cyclones are a serious threat to wind energy technology in the Pacific and can do significant damage when an extreme cyclone directly hits a wind generator. Secondly, even if on site measurements of the wind regime is performed, actual yield can fall short of the predictions of even sophisticated models.

It is interesting to note that the Plum 2.7 MW wind farm used the same technology favoured in the UNDP/UNESCO proposal for Cook Islands: The project consisted of 20 Vestas 225 KW generators on 32 meter lattice towers. The machines were equipped with dual generators (50 and 225 KW), with the smaller unit starting to harvest wind energy from a speed of 4 m/sec. The farm was also remotely monitored by the manufacturer (VESTAS). It fed into a 15 KV distribution network that peaks at around 6 MW and reaches its lowest loads at 2.5 – 3 MW. The backbone of the local distribution network is a 33/15 KV substation that provides spinning reserve, maintains system stability and meets any shortfall in supply by the wind farm. This arrangement allows using practically all energy generated by the wind farm.

Operational experience with the Plum wind farm project in New Caledonia provides insights with respect to wind energy forecasts and outputs achieved. The project design and forecast were based on two years wind measurements at hub height at the wind farm site. Prior to project installation. the supplier of the turbines analyzed the measurements and predicted an annual supply of 6000 MWh, or average monthly wind energy of 500 MWh. Data provided by the utility showed a shortfall of 10% on these estimates for the first 24 months of operation. This experience shows that even with a good database and an excellent modelling technique, there is a risk of overestimating wind energy production. A comparison of capacity factors also indicates optimistic assumptions in the UNDP/UNESCO proposal.

The wind farm was unfortunately severely damaged by cyclone Erica in March 2003.

Cyclone Damage to Plum wind farm, Source: Small Wind Industry Implementation Strategy)

5 Turbines were completely destroyed, the towers of 12 collapsed and 3 maschines suffered light damage.
It took more than two years to rehabilitate 15 of the 20 generators originally installed.

Damage without considering lost generation was approx. 50 % of the initial investment. This cyclone had record wind speeds with gusts above 200 Km/h. At sea it had an eye pressure of 920 hPa, with the associated wind speeds of 280 km/h. The New Caledonian power utility has, also 10 Vergnet 220 KW generators mounted on tiltable towers (Col de Prony Wind Farm) These generators were lowered during Erica and suffered a damage of 2% of the initial capital investment.

### Fiji

The Fiji Electricity Authority is currently installing a 10 MW wind farm at Butoni on the west cost of the main island of Viti Levu. The project is part of an ambitious plan to generate all of FEA's electricity supply from renewable resources.

The projected output of the farm is conservatively assumed to be 11.4 GWh per annum with a corresponding plant factor of 13%, less then half of the value assumed in the UNDP proposal for Rarotonga. The project budget is in the order of FJ$ 30,000,000. The project uses French Vergnet generators having a rated output of 275 KW each.

## *3.3 Wind Generators for the Rarotonga System?*

There are pros and cons to consider when introducing a new energy technology into an economy such as the Cook Islands, characterized by a small energy market, remoteness, and limited technical capacity.

### Diversification of a generation portfolio

Wind as a renewable energy source has a variety of benefits for a generation portfolio. In the power industry, resource diversity is recognized as the basis for efficient resource portfolio management. At present, TAU is in the worst possible position in this regard: its generation depends entirely on a single resource, i.e. imported diesel fuel consumed in piston engines. Wind, biomass and solar energy, available in the Cook Islands, would help to diversify generation sources. Diversity of fuel type provides some safeguard against fuel supply shortages (problems in the fuel supply chain) and volatility of fuel prices, which may improve the reliability of the whole power system. Wind-diesel hybrid configurations (i.e., wind connected to a diesel grid) are a proven means to reduce risk. Wind protects the utility against price volatility on international energy markets and diesel protects the system against wind energy's intermittent nature.

The wind energy proposals are modular and their individual components are scalable. This modularity and flexibility of wind generation makes the TAU utility less susceptible to the risk of generation capacity loss and over-investment in new power plants. Once the capital investment is made, the fuel is free and marginal operating costs are very low. They are not tied to purchased fuel and are therefore known and stable over the lifetime of the project. This has a stabilizing effect on electricity production costs and possibly tariffs.

Provided that the site selected for wind generators has an adequate wind regime (in the order of 7 m/sec average wind speed), wind is the lowest-cost renewable energy resources available. Including wind in TAU's generation portfolio could thus contribute to maintaining lower long-term electricity costs. Because renewables have fewer negative environmental impacts than fossil fuel based technologies, they are not susceptible to changes in clean air regulations, new pollution taxes, or to future restrictions on greenhouse gases and air toxics. There are thus good reasons for considering a diversification of the Cook Islands generation portfolio through commercial wind energy.

### Environmental impacts

Substitution of fossil fuel through wind energy reduces the production of pollutants and greenhouse gases. In addition, the environmental risk associated with fuel and lubricant handling would be somewhat reduced through a reduction in the quantity of fuel that needs to be handled. These additional benefits are desirable but should not be overestimated. Local airborne pollution from combustion of fossil fuels does not pose a problem in the Cook Islands. The country enjoys one of the best air qualities in the world. Although saving of fossil fuels is certainly a desirable objective, reducing diesel consumption by 1000 tons p.a. would not make a significant difference in Raratonga's air quality. The UNDP/UNESCO proposal mentions potential benefits from building a "green image" [10]. Though difficult to quantify, there might indeed be some cross-sectoral linkages with the tourism sector.

The Cook Islands is vulnerable to the impacts of oil spills and inadequate disposal of engine oil. The introduction of wind energy would only marginally reduce these risks and should not lead people to believe that conventional risk mitigation strategies are no longer required because some of the fuel is substituted for. The reduction of greenhouse gas emissions is certainly welcome, but once again, one should not overestimate the effects of a comparatively small project. The most important aspect is that the reduction of greenhouse gas emissions qualifies for financial rewards per unit of saved $CO_2$ equivalent from GEF, the Prototype Carbon Fund or other carbon trading schemes that are emerging. Fiji's FEA has managed to sell the carbon credits that its 10 MW wind farm in Butoni will produce to

### Introducing complexity

Commercial wind energy would increase the level of complexity in the Cook Islands power industry and would require the acquisition of new skills and knowledge locally. This has been demonstrated in the framework of the Mangaia project. While it is understood that technical skills are in short supply, this should not be a reason to hesitate with the introduction of wind generators. Firstly, there are several effective modalities to ensure an effective transfer of technology and to build local expertise, as discussed below. Secondly, development is about the acquisition of new knowledge, skills and technology and the Government of the Cook Islands should not hesitate to take on such a challenge if it leads to an economically viable utilization of an indigenous, renewable energy source. Thirdly, wind turbines are now a mature and reliable technology[11]. With improved knowledge about the actual behavior of

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[10] Surveys in New Zealand have shown that the countries 'clean, green' image provides a significant attraction for visiting tourists

[11] In the early 80s, the first-generation wind turbines installed in California were difficult to operate and had many failures, some quite spectacular. These early operational problems were the result, in part, of inadequate understanding of the wind gust forces on the flexural or fatigue failure modes of structural components.

wind (gust structure), the development and widespread use of improved modelling and design tools, improved manufacturing techniques, and millions of hours of operating experience, the reliability of current wind turbine designs has improved dramatically.

The reliability improvements encompass not only the major structural components but also power electronics and supporting control systems of the wind turbine. As a result of considerable competitive pressure in the industry there have been improvements in the quality assurance programs of manufacturers. Designers have given significant attention to the maintainability of the wind turbines. The interval between major overhauls has been extended, for example, from five years to 10 years or more. It should also be noted that wind generators have been successfully operated in remote island locations quite similar to the Cook Islands. Cape Verde, for instance, a small Island state off the African Atlantic coast, has operated two wind projects since 1996. The diesel grids to which the wind generators have been connected are of a size similar to the Rarotonga system and show similar load characteristics. The data for some wind-diesel hybrid projects are summarized below.

**Table 2. Examples of wind-diesel systems and small wind farms in operation**

| **Location** | Operation | Diesel (KW) | Wind (KW) | Wind Penetration % |
|---|---|---|---|---|
| **Sal, Cape Verde** | 1994-2005 | 2x500<br>1x800<br>1x620<br>1x400 | 2x300 | 14 %, max 24 % per month |
| **Mindelo, Cape Verde** | 1994-2005 | 2x2300<br>2x3300 | 3x300 | 14 % |
| **Dachen Island PRC** | 1989 – 2005 | 2x280<br>2x100<br>1x560 | 3x55<br>2x20 | 15% |
| **Marsabit, Kenya** | 1989-2002 | 1x100<br>1X200 | 1x150 | 46% |
| **King Island Australia** | | 4 X 1200 | 3X250<br>2X850 | 30 % |
| **Plum, New Caledonia** | 1996-2006 | N.A. | 20x225 reduced to 15 after 2002 | Approx 3 %, 30% at local distribution voltage level |
| **Col de Prony I New Caledonia** | 2002- 2006 | N.A. | 10x220 | NA |
| **Col de Prony II New Caledonia** | 2003- 2006 | N.A. | 21x220 | NA |
| **Col de Prony III New Caledonia** | 2005- 2006 | N.A. | 20x275 | NA |
| **Kafeate I and II New Caledonia** | 2004 - 2006 | N.A | 42x275 | N.A. |

### Resource risk

The resource risk can be significantly reduced through adequate data recording and smart modeling, but cannot be completely eliminated. This risk has to be allocated to a party participating in the project; that is, someone has to be responsible to absorb the effects of higher cost of electricity generation that would result from a generation shortfall. For a BOOT project, for instance, shortfall of revenue in comparison with the agreed energy model can have serious consequences in the debt service period and can, if not properly managed, lead to default of a developer. At present, wind data available for the Cook Islands (in particular for the project site) appear to be insufficient to take an investment decision for a major project such as proposed by UNDP/UNESCO or other investors. Further investigations are strongly recommended. This aspect is further discussed below.

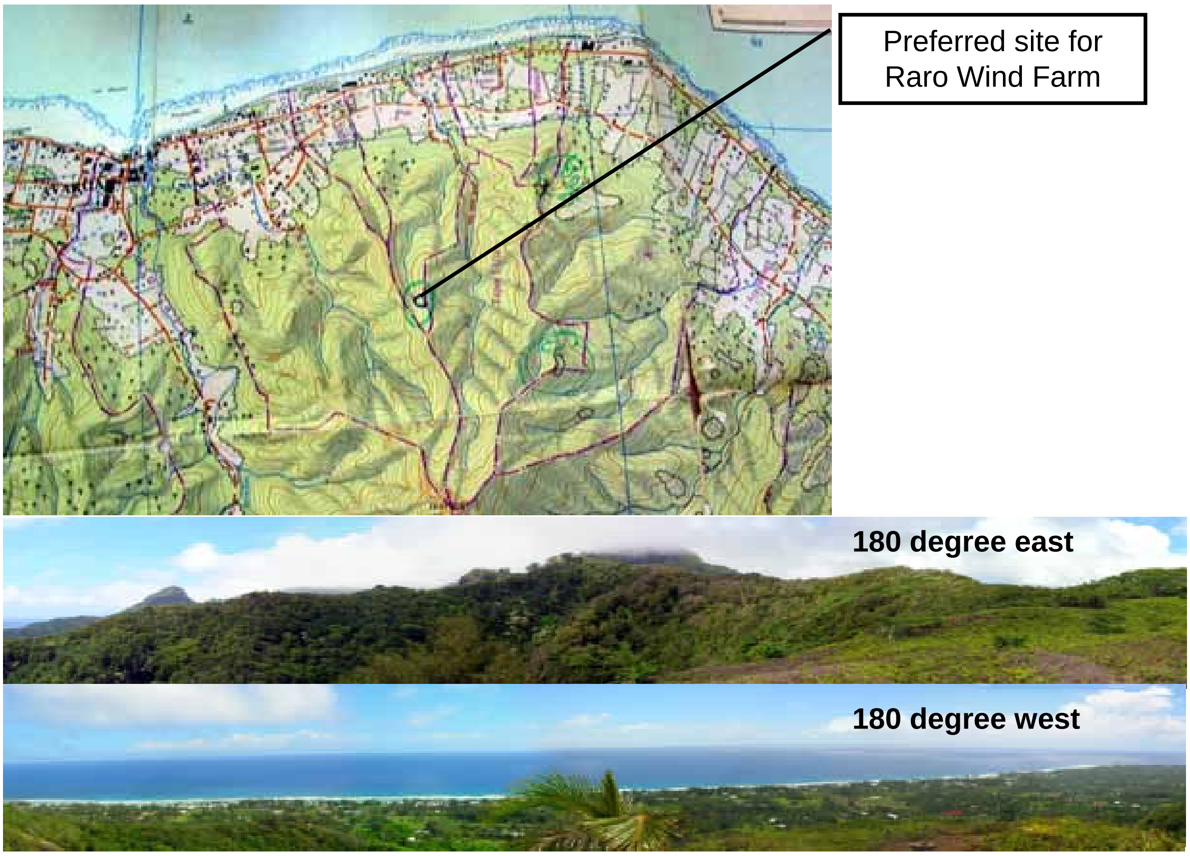
# 5.0 Design and Technology Choice

## *5.1 Siting Considerations*

With respect to sites for a wind farm there are not too many options in Rarotonga. Sites on the coastal strip (such as Ngatangiia where the wind measurements took place) are not suitable as the generators would be too close to buildings. What remains are the ridges of the islands interior. Considering access and availability of land leaves three sites in previous studies referred to as B1, B2 and C. Site C seems to be the most favourable as it combines accessibility and proximity to the grid and load centers with a position of low wind flow disturbance. Construction of a wind farm will require major earth moving and civil engineering but this is essentially true for every possible site in Rarotonga.

The map below shows the location of site C and two panoramic photos displaying both the eastern (landwards) and western (seawards) view.

**Chart 2: Project Location**



It is unlikely that wind generators larger than 300 KW can be moved up the ridge and installed with acceptable effort in civil engineering and crane capacity.

### *5.2 UNDP/UNESCO Proposal*

The UNDP/UNESCO report proposed a 1.8 MW wind farm that consists of 8x225 KW proven, commercial-grade wind generators. The wind turbines with large swept rotor area relative to generator rating were recommended, in order to provide for high average wind energy penetration by reaching a stable peak output at relatively low wind speed. Sizing considerations for the individual machines included system redundancy, transport and crane limitations and power quality considerations, in particular flicker.

An 1100 KW water or air-cooled load bank with a switching solution of 6 KW and ancillary power electronics was proposed for load management. Location of the load bank is kept open with a suggestion that a site close to a potential demand for process heat could be beneficial.

Wind system and load bank monitoring and control by a SCADA system were proposed that would also allow remote data wind generator monitoring via satellite up-link. In addition, a grid interface module would allow monitoring of the diesel generators without, however, rights to control the diesel portion of the system. A minimum diesel load was defined, above which wind would be first merit order dispatched, with shortfalls being filled by additional diesel generation. While the wind generators were fully SCADA-controlled, the diesel dispatch system remained manual.

While this proposal is considered sound, the design of the wind farm should be left open. Instead clear technical specifications should be provided to either a turn key supplier of the wind farm or to an IPP developer. A few design considerations are discussed below.

### *5.3 Design Considerations*

Turbine Technology

In a situation where commercial wind energy is first introduced, only proven technology with a strong track record and very good manufacturer guarantees should be considered. The wind regime in the Cook Islands and in much of the Pacific is characterized by moderate trade winds, which calls for wind turbines having a large swept area in relation to power output. Preference should be given to generators with specific power outputs of 0.38 KW/m$^2$ or less. In general, these are three-bladed designs. The machines should have good slow wind performance, i.e. designs incorporating two generators might be preferable.

On the international market there are various models of generators available that fall into the suggested power range. As manufacturers have all tried to reduce specific investment cost through the design of larger generators, the variety is larger in the 750 KW class. Examples of machines are listed in the table below together with their power output per m$^2$ swept rotor area. Not all of these machines are still being produced, but those that are no longer available as new machines can be found as refurbished machines on the second hand market. Table 3 below provides an overview of wind generators in both the 250/300 and 750 KW range. It should be noted that not all machines are still in commercial production. Some units may only be available on the second hand market.

**Table 3: Various models of wind generators in the proposed range**

| Model | Rated KW | Swept area m$^2$ | kW/m$^2$ | Hub height m |
|---|---|---|---|---|
| | **2250/300 KW Class** | | | |
| **Bonus 300 KW MK 3** | 300 | 875 | 0.34 | 30 |
| **Nordex N 29/250** | 250 | 693 | 0.36 | 31.5 |
| **Enercon 30** | 300 | 707 | 0.33 | 36 |
| **HSW 250 T** | 250 | 638 | 0.39 | 29 |
| **Micon M 700-225** | 225 | 697 | 0.32 | 36 |
| **Fuhrlaender FL 250** | 250 | 683 | 0.36 | 42/50 |
| **VESTAS V 29/225** | 225 | 661 | 0.34 | 33 |
| **Windtechnik Nord 250** | 250 | 661 | 0.38 | 30 |
| **Lagerwey 30/250** | 250 | 707 | 0.35 | 40 |
| **Vergnet GEV MP** | 275 | 803 | 0.34 | 50 |
| | **750 KW Class** | | | |
| **Enercon 58** | 850 | 2642 | 0.32 | 70 |
| **Frisia F48/750** | 750 | 1810 | 0.41 | 48 |
| **Fuhrlaender FL 800** | 800 | 1808 | 0.44 | 48 |
| **Lagerwey 50/750** | 750 | 2003 | 0.37 | 51 |
| **Nordex N 52** | 800 | 2124 | 0.38 | 60 |
| **Seewind 52-750** | 750 | 2125 | 0.35 | 65 |
| **Suedwind S 50/750** | 750 | 1963 | 0.38 | 74 |
| **Vestas V52-850** | 850 | 2124 | 0.40 | 44 |
| **NM 750/48** | 750 | 1824 | 0.41 | 45 |
| **Ecotecnia 48/750** | 750 | 1838 | 0.41 | 45 |

It is proposed to limit wind energy capacity on Rarotonga to approximately 2 MW with an annual gross production of approximately 4.0 GWh according to the site-specific conditions. The wind generators should preferably be in the 250/300 KW range as site access and crane capacity are serious restrictions for larger machines. The wind turbines shall preferably be procured to a strictly performance based specification, i.e., with specific emphasis on proven and guaranteed longevity, output and grid behaviour.

The generators should have design survival speeds of at least 75 m/sec. This has to be applied for all technology employed in the project (wind generators, power lines etc). The wind turbines shall be independently design verified according to recognised industry standards by an internationally recognized certification company such as Det Norske Veritas, Germanischer Lloyd, or similar. Also, the turbine manufacturer shall be certified according to the international quality standards defined by ISO 9001, thus ensuring that not only the manufacturing process, but also the development, delivery, installation, maintenance and service of wind turbines is embraced by the company's quality procedures.

The power curve of the wind turbine would have to be documented and certified by an internationally recognised and independent third party in accordance with IEA, "Recommended practices for wind turbine testing and evaluation".

Storage Facility

Short-term wind variability limits the penetration of wind in small systems. Available storage technology can optimise the amount of wind energy to be fed into the system without increasing frequency instability and voltage fluctuations. These fluctuations are potentially harmful to electrical equipment and power system operation.

In its King Island power system Hydro Tasmania uses large flow batteries as a short-term energy storage measure. Flow batteries have mainly been used to assist with load levelling for substations and in buildings or in small isolated storage systems. Their use in larger-scale power supply systems is relatively new but reports indicate that the technology is ready for replication. Transient response to millisecond events such as voltage sags or motor starts is a standard capability of a flow battery system.

The commissioning of the King Island Vanadium Redox Battery Energy Storage System ("VRB/ESS") was completed in 2003. The VRB/ESS is used to smooth the short-term output variations in the wind generators and the system loads whilst providing frequency and voltage control through load shifting. The system also provides reactive power support. The control system includes a Rockwell Automation Allen-Bradley-brand Programmable Logic Controller (PLC). The presence of the VRB/ESS has raised the level of usable wind power and has allowed for the ability to provide "firm capacity" from the existing wind generation. Operation cost of the system are estimated to be in the range of 0.2 NZ cents per KWh. A flow battery system has only low maintenance long life pumps as moving parts. They require replacement every 5 to 7 years. Other operations and maintenance costs are limited to regular system checks.

### *5.4 Operational Considerations*

Output to Load

In a wind-diesel system, the power output from the wind turbines must be limited never to exceed the safe operational limits of the combined wind-diesel system. Typically, the maximum instantaneous wind energy penetration should not exceed approximately 65 percent of the total system load. Load management facilities can improve penetration and also assist in maintaining systems stability.

A load management system allows for the diversion of excess electrical energy during time periods when low facility load happens to coincide with high wind speeds. It is obvious that with minimum over-night loads of about 1500 kW and a proposed wind farm output of 2000 kW, there will be times when load and supply from the wind generators do not match.

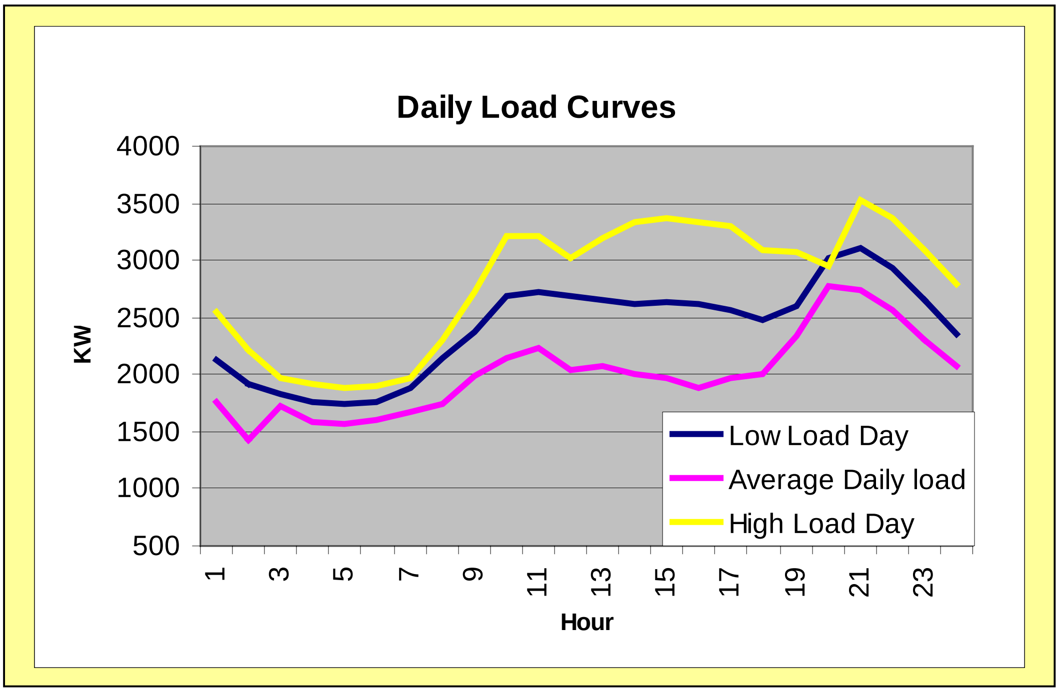
The UNDP proposal was based on a load bank where excess energy would be dumped. The load bank matches the output of the wind energy system to the instantaneous demand and the output of the diesel generators and provides fast smoothing of power fluctuations that could otherwise result in voltage fluctuations. Also, the smoothing of the power output provides for clean combustion and optimum fuel efficiency at the diesel power plant. The control of the load bank includes an operator programmable set point for minimum diesel generator production and self-diagnostic features for monitoring of the load bank. UNDP has used 1050 KW as the minimum setting for the purpose of their proposal.

Minimum Operator Set Point:

The operator programmable set point in the system will determine the stable minimum power allocation to the diesel plant, thus ensuring that the diesel engines operate at maximum efficiency at the given load. At the Rarotonga diesel power plant, the smallest diesel engine is rated at 600 kW. Hence, considering that diesel engine manufacturers typically specify a minimum continuous operational limit of 40-60% percent of rated power, theoretically a minimum set point of approx. 300 kW could be introduced. However, before considering operating the system with only one of the smallest diesel generators engaged in parallel to the wind turbines, a certain safety margin of energy to the load bank would need to be produced. This is to prevent overpowering the diesel generator in connection with normal fluctuations in the consumer demand and/or in the available wind speed. Just as important, the setting would have to ensure that the reactive power demand could be covered in any operational condition by the available diesel generator(s). Preliminary analysis of this criterion reveals that without additional capacitor compensation the electrical system would require a minimum diesel generator capacity of 2 x 600 kW in order to cover both the reactive and apparent power demand in any combination of load and wind power input. This, in turn, leaves a theoretical minimum diesel set point of 600 kW at 50% minimum load. However, in order to establish a versatile minimum set point that can be covered at high fuel efficiency with all combinations of existing generators, an initial set point for minimum diesel generator load of 1050 kW is proposed. This setting will ensure that the specific fuel efficiency will be maintained at a high level relative to the current mode of operation. Reduction of the minimum set point during the operational phase is technically a matter of changing the operator programmable set point in the SCADA system. The incentive to reduce the minimum set point is of course higher utilization of “free” wind energy and, consequently, better overall system economics. Hence, during the operational phase TAU and the system supplier should critically evaluate the optimum set point for minimum diesel generator load. The minimum operating load is a significant technical issue but it is easily tractable and given the potential economic benefit worth optimising during the operational phase.

Rarotonga’s daily load curve is typical for a small system with a low night-time load, a day time air conditioning load and a high domestic load that consistently creates the system’s evening peak. The introduction of wind as a fuel saver will increase the need of diesel generator switching if optimal fuel efficiency is to be achieved. In other words, the system operator has not only to follow the daily load curve, but must also consider the varying contribution of the wind farm. Here, the limitations of a load bank become obvious. As the facility is strictly passive, it has no capability to support the system with active or reactive power. In the meantime technology has advanced and for the case of Rarotonga it is worthwhile to consider a fully integrated SCADA-controlled automatic operation of all generators together with a battery buffer. Whether a load bank is still necessary is an optimisation consideration and should be left to the system designer/supplier to decide. The inclusion of an active load management capability would help to optimise fuel efficiency and assist in maintaining power quality. It would also avoid wasting precious electrical energy in a dump load.

**Chart 3: Daily Load Profiles, Rarotonga**



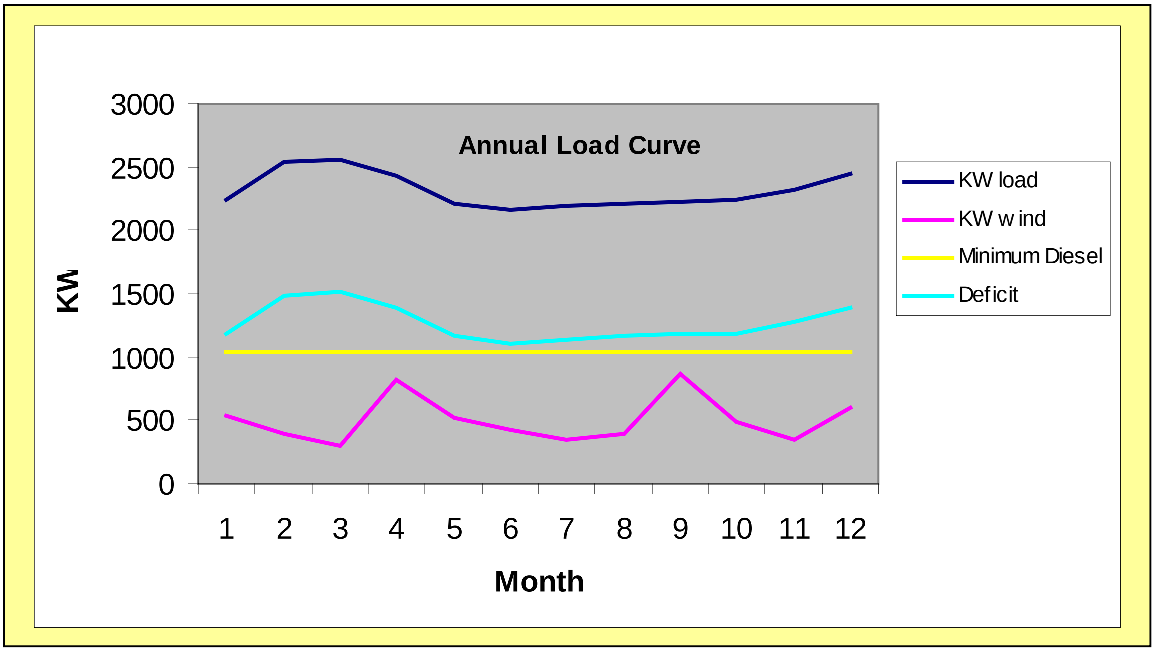
For any configuration above 500 KW, deductions have to be made to accommodate this mismatch between wind energy supply and load when calculating net energy production. In order to estimate these losses, both daily and annual load curves need to be compared with the anticipated wind regime. The more correlated these profiles are, and the more battery buffer is available, the more the wind-generated electricity can reliably supply part of the load. The average diurnal wind speeds at Ngatangiia show very little variation, always more pronounced on light windy days than on days with high winds. Therefore, the diurnal variation is not likely to result in an accelerated negative effect on the fit between load and wind energy supply. Availability of battery storage would of course be very helpful in smoothen diurnal variations.

The UNDP/UNECO proposal has not given the wind generation a capacity credit, i.e. it is not assumed that there will be close match between wind energy and load profile. With additional wind measurements, and in particular with addition of a battery buffer such a capacity credit could be allocated to the wind farm, increasing its value.

The annual load profile is also important to the supply-to-load match as there are significant seasonal variations in both load and wind energy flux. Using available data for load and the wind resource, monthly values have been compared using the average monthly energy flux for Nagatangiia adjusted for an overall annual production of approx 4,000 MWh and the average monthly load of the Rarotonga system. It is assumed that the minimum power setting for the diesel units is 1050 KW, in line with the UNDP/UNESCO proposal.

This analysis is not a simulation of wind energy as a negative system load. It is simplified, based on limited data, and can only detect a major mismatch between load and supply. As shown in the following chart, load profile and wind output do not always fit. In particular, there seems to be higher air conditioning loads in the system during the summer months that coincide with lower wind energy flux. Dumping load, or battery charging on the other hand, is more likely to occur in April and September when high wind speeds coincide with a lower system load. In average, however, the deficit above the 1050 KW minimum diesel setting is always larger than the average load provided by the wind park. The assumptions made in the UNDP/UNESCO proposal that 7% of the wind park's energy would be dumped in year 1 are therefore considered adequate.  With battery storage in the range of 800 KWh, it is estimated that only 3 % of the wind output would have to be forgone through regulation of the generators. It should also be noted that these losses would proportionally decrease with a lower gross average energy production. Load growth, which typically lifts the entire daily load curve up also reduces the mismatch losses over time.

**Chart 4: Annual Load Curve**



### *5.5 Power Quality*

TAU has expressed concern about the technical characteristics of the electric power provided by a wind farm. Taken together, these characteristics often are referred to as power quality. Besides variability with time, other power quality parameters include

- Power factor
- Voltage fluctuations
- Harmonic distortion
- Frequency deviations.

A low system power factor causes losses and reduces the capacity of power plants. Wind generators equipped with induction generators require reactive power from the grid for excitation, i.e. they lower the system power factor. In addition, the step up transformers required also consume reactive power. These parameters together with the reactive power consumption of electric motors within the system have to be taken into consideration when specifying the permitted reactive power consumption of a wind farm. There are numerous technical solutions available, from simple shunt capacitors (with limited lifetime due to the surge currents when switching), to Thyristor Controlled Reactors (TCR) and inverters with force commutated switches. These advanced “power electronics” are based on fast acting switches that allow controlling reactive power and automatically eliminating harmonics.

Wind generators that use the inverter-based technology such as the Enercon machines or the use of active load management through battery or flywheel storage are proven means insuring adequate reactive power control.

Over a significant range of operating wind speeds, the electrical power output of a single wind turbine corresponds closely to the temporal characteristics of the wind flow field incident on the wind turbine. This causes voltage fluctuations. Although the inertia of the rotor averages out somehow short-term fluctuations may cause flicker emissions that concern utilities and consumers. In extreme cases, voltage fluctuations can cause a voltage collapse as voltage drops result in increased reactive power consumption that causes a further drop in voltage. Again a battery bank equipped with a smart inverter would help significantly to reduce voltage fluctuations.

The electrical power output of a wind farm using six to eight generators for 2 MW is considerably smoothed relative to that of a single turbine. The reason for the smoothing is that the wind gust structure, both in space and time, typically becomes increasingly uncorrelated over distances greater than several rotor diameters. Relative to the fluctuations of a single wind turbine, a complete lack of correlation would imply that the fluctuations in the wind farm electrical power output are reduced by the square root of the number of uncorrelated machines contributing to the power output.

The degree of smoothing depends on the geographical extent of the wind farm, the average wind speed, the control characteristics of the wind turbines and, finally, details of the terrain and how they influence the distribution of wind speeds across the wind farm. Although data to accurately assess voltage fluctuations caused by the wind farm are not available, voltage fluctuations are not considered to cause serious problems in the Rarotonga system, particularly if a load bank is employed for load management and the wind penetration in the power system is limited to 60 – 70%. Voltage fluctuations due to changes in power output should not exceed 1% at the interconnection point. (This value can be used as a power quality specification if the facility is independently operated).

The wind farm should also not cause excessive harmonic voltage distortions on the TAU’s system. A typical specification for an installation would be that the level of negative phase sequence voltage on a three-phase system at the interconnection point should not exceed 1.3% of the positive phase sequence voltage, assuming an initially symmetrical system.

Wind generators are more likely to suffer from frequency fluctuations, rather than cause them. However, system frequencies below the 50 Hz level will cause an increase in reactive power consumption of the wind generators and thus feed back into the system. Also, frequency fluctuations change the synchronous speed of generators and may cause aerodynamic losses.

Although power quality problems are unlikely to occur with modern generation equipment, the wind park should have a clearly labeled switch for isolating the facility from the TAU's system when output, as measured at the Interconnection Point, does not meet voltage and/or frequency specifications. This switch should be lockable in the open position and authorized TAU personnel should have access to this switch at all times. The switch should be located close the metering point of the facility.

### *5.6 Availability and maintenance*

The impact of the design and manufacturing advances achieved over the past 15 years has shown up not only in increased availability but also in reduced costs of maintenance for systems manufactured by reputable companies. Availability has increased from values near 60% in the 1980s to values between 98 and 99% for recent wind farm installations. Over this same period, maintenance costs have been brought down from more than 2.5 Euro cents/kWh to less than 1 cent/kWh in modern designs. For the purpose of this study, it has been assumed that the maintenance can be contracted for 1.7 Euro Cents (2.5 Cents NZ) as this is the rate for the Prony wind farm in New Caledonia.

Manufacturers are able to remotely monitor the generators and are willing to provide considerable warranties covering the technical performance of their systems. Insurance is also available for certain types of machines. Nevertheless, special training would be required in operation and maintenance of the systems in case TAU wants to operate the units. Whether TAU would need to hire additional staff to cope with the work related to the wind generators will depend on the current workload of the operation and maintenance crew[12].

The UNDP/UNESCO proposal specifies a five-year maintenance contract during which period local staff would be trained. Under such an arrangement the turbine supplier or manufacturer would guarantee the performance of the wind energy system directly to TAU and be economically liable in case of shortcomings. This is considered adequate in a model where TAU is the owner and responsible for the operation of the plant. Good spare part management will increase availability but, due to the modular design of the wind park, unplanned outages are not likely to affect several machines at the same time. That is, even if spare parts have to be ordered from suppliers, the loss in energy due to down time will not be severe.

### *5.7 Installation of Wind Parks*

The installation of a wind park consisting of machines in the output range of 300 KW or above requires skills and equipment that are not readily available in the Cook Islands. Critical inputs are handling and transport capacity for large parts such as rotor blades (15-25 meters long), nacelle, tower, and installation equipment. Most manufacturers ship their wind generator parts in special containers that need to be transported to the installation site. There are two ways to erect wind generators up to the 300 KW range: Erection of the entire assembly by jute pole and sequential assembly of the units by crane.

The critical part is usually a heavy-duty crane that is able to lift the rotor and nacelle to hub height. In case of the 300 KW generators the heaviest part is the nacelle. It weighs approx 10 tons and requires a crane that allows positioning of the unit with a high level of precision. The rotors are approximately 5 tons per machine; a 32 meter

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[12] EEC New Caledonia had 6 of its staff trained in wind park operation and maintenance, but did not hire additional staff.

lattice tower weighs 9 tons. As it would not be cost effective to acquire equipment and skills to perform the installation locally, it is recommended that the installation of the wind generators be left to a specialized contractor who would also be responsible for sourcing the required transport and lifting equipment.

Other installation considerations

Site preparation for wind generator technology of the proposed rating requires geo-technical investigations and considerable civil engineering work. Each individual generator is placed on a platform that consists of a foundation, a tower assembly area, elevator crane parking and a rotor assembly area. Ground conditions have to be known in order to design the generators' foundations.

It is not clear if the project budgets have accounted for these investigations. Due to unfavorable ground conditions, 3 of the 12 generators installed in Plum had to be placed on costly special foundations. Wells had to be drilled 30 meters deep and filled with reinforced concrete in order to secure the installations, involving considerable additional cost. The project also required the services of a heavy-duty helicopter that lifted the pylons for the 15 KV interconnection line to the sites. This was essentially an environmental requirement, as the interconnection line was routed over fragile steep terrain where the opening of an additional road would have caused serious erosion. It is understood that a full EIA will be performed for the Rarotonga projects and it is recommended that an independent party be engaged to perform the EIA.

Though wind technology is environmentally friendly, care has to be taken to avoid negative environmental impacts during installation. When delivering 8 or more large wind generators to the installation site, a huge amount of material must be transported. Besides towers, blades and nacelles, there are the various components that go into the finished wind turbine. All of this must be carefully packaged to protect the machinery during transportation and handling. This generates a pile of discarded packaging, boxes, plastic bags, styrofoam and various other materials. These can be difficult to control since wind farms are located in windy locations. After installation, there will be additional garbage such as containers used tools, pieces of metal, cables, etc. Adequate provision to dispose of all these materials has to be made and included in project cost estimates.

# 6.0 Costing

## *6.1 UNDP Proposal*

The UNDP proposal of 2002 estimated investment cost of NZ$ 8.6 million. While specific cost estimates for the generators (including SCADA, load bank and installation cost) are considered conservative, cost for civil engineering and design may be optimistic. The following table compares the cost of the Ploum 2.7 MW project and the Rarotonga proposed 1.8 MW project. Data for the 10 MW wind farm for Butoni Fiji are also provided, however, a detailed break down is not available for this project. The 1996 cost for Plum, New Caledonia has been adjusted for 3% price inflation to 2002 NZ$. Costs for warranty, maintenance contract, and lease have been excluded in the comparison as they are more appropriately considered as operating cost.

The significantly higher generator costs for the Rarotonga project reflect additional equipment such as Load Bank and increased handling and installation costs[13]. International competitive bidding of an Engineer Procure and Construct (EPC) contract could perhaps reduce these cost by NZ$500,000–$800,000. On the other hand, in line with international practices, it seems advisable to include a contingency budget in order to cover unforeseen ground conditions, bad weather, delays etc. NZ$500,000 is considered adequate for this.

It is also recommended the environmental impact assessment (EIA), estimated at NZ$80,000, and geo-technical investigations, estimated at NZ$150,000, be included in the design work.

**Table 4. Comparison of investment costs, Plum and Rarotonga**

| Item | Plum | | UNDP Raro | | Butoni Fiji | |
|---|---|---|---|---|---|---|
| | NZ$ | NZ$/kW | NZ$ | NZ$/kW | NZ$ | NZ$/kW |
| **Generators** | 7,452,533 | 2,760 | 6,852,091 | 3,807 | | |
| **Foundations** | 1,379,336 | 511 | 433,659 | 241 | | |
| **Terracing** | 1,564,620 | 579 | 407,544 | 226 | | |
| **Network** | 2,120,472 | 785 | 731,980 | 407 | | |
| **Design** | 905,833 | 335 | 156,827 | 87 | | |
| **Total** | 13,422,795 | 4,971 | 8,582,101 | 4,768 | 25,600,000 | 2,564 |

Exchange rate 1 NZ$ = 1.17 FJ$

Salvage value, UNDP/UNESCO project

Although no salvage value is assumed in the economic analysis, it is argued in the UNDP/UNESCO proposal that this is a conservative assumption as there might be value in the installation after 20 years of operation. This view is not supported. Whatever there might be in terms of salvage value, decommissioning costs that are often included in project budgets will probably offset it. Decommissioning charges include removal of turbines, restoration measures, and landscaping[14].

### *6.2 Operating cost, UNDP/UNESCO project*

The proposal assumes an operation and maintenance (O&M) cost of NZ$15,000 per year per machine. This translates to approximately 2.8 NZ cents per KWh and is in line with international experiences. Given the remote location, corrosive sea climate and the lack of experience with the technology, it does not seem to be a conservative estimate as stated in the proposal. Also, a pro rata reduction of variable O&M cost for the diesels has been assumed due to reduction in operating hours. Although only 2/3 of the savings have been calculated, this assumption is considered optimistic.

Firstly, it is not known with certainty what effect the introduction of wind energy will have on operating hours of the diesels. Due to unfavorable combinations of system load and generator capacity, the actual saved operating hours might be significantly lower than suggested by the saved energy production. Secondly, the introduction of

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[13] For the Plum installations for instance a local crane could be hired.

[14] Best Practice Guidelines, British Wind Energy Association.

wind with its inherent variation will require an increased switching of the diesels, a factor that has a negative effect on O&M cost. Reduction of these savings to 1/3, i.e. to NZ$0.013 per kWh, is therefore recommended.

### *6.3 Assumptions for the purpose of this Study*

#### Investment cost

Investment and operation cost assumptions used in the following economic analysis are summarized below. The cost assumptions are based on indicative costs provided by wind turbine suppliers and developers. As the base reference the UNDP proposal has been used. New items such as a flow battery bank have been included. There are conservative estimates made for foundations and terracing. These cost must be confirmed in a full feasibility analysis that included geotechnical investigations.

**Table 5 Investment Cost 2 MW Wind Park Rarotonga**

| Item | Cost | | Remarks |
|---|---|---|---|
| | NZ$ | NZ$/kW | |
| **Generators** | 4,400,000 | 2200 | Based on Fuhrlaender FL 250 50m |
| **Transport CIF** | 220,000 | 110 | 5 % of ex factory price |
| **Foundations** | 1,000,000 | 500 | Based on experiences in New Caledonia |
| **Terracing and access** | 1,200,000 | 600 | 2000 m3 of earthwork and 2 km access road |
| **Network, transformers** | 1,600,000 | 800 | Based on experiences in New Caledonia |
| **Battery and inverter** | 560,000 | 280 | 800 KWh/250KW Redox Unit at NZ$ 700 KWh |
| **Design, geo-technical, EIA** | 700,000 | 350 | Based on experiences in New Caledonia |
| **Miscellaneous** | 500,000 | 250 | Unforseen ground conditions, landowners |
| **Total** | 10,180,000 | 5090 | |

#### O&M Cost

With respect to operation cost, real figures from contracts that have been concluded in the region (New Caledonia) are used. This is a substantial deviation from assumptions taken in earlier analysis. Operating costs are essentially divided into management of the wind farm under a management contract, spare part supply and insurance cost. These cost are expressed in cost per KWh assuming that a management contractor operates the facility. These costs would essentially be the same for an IPP developer. Either the developer had to hire an operator under a management contract or incur the cost. It should be noted that these figures are typically lower in current contracts in Europe. Given the remote location and the risk exposure it seems however prudent to be conservative.

**Table 6 Operating Cost 2 MW Wind Park Rarotonga**

| Item | Cost | | Remarks |
|---|---|---|---|
| | Euro/KWh | NZ$/KWh | Exchange Rate 0.56 |
| **Management Contract** | 0.017 | 0.030 | Based on the Biotech contract NC |
| **Insurance** | 0.006 | 0.011 | Insurance by Axa for Prony NC |
| **Spare Part Provision** | 0.007 | 0.013 | Based on Biotech contract NC |
| **Miscellaneous** | 0.001 | 0.002 | Additional Risk, Landowner royalty |
| **Total** | 0.031 | 0.056 | |

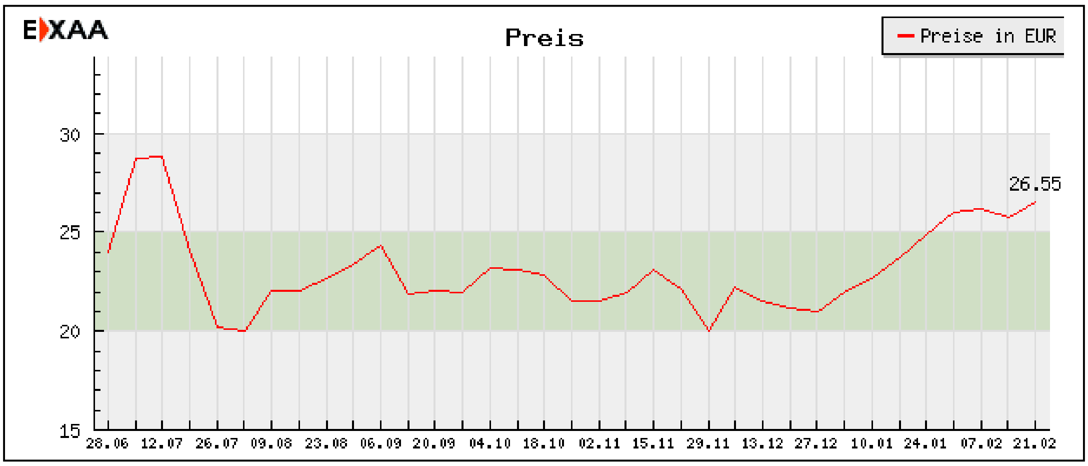
# 7.0 Economic and Financial Analysis

## *7.1 Financial analysis*

It is safe to assume that the wind project’s financial performance will not be bankable under strictly commercial terms. This characteristic, however, qualifies the wind energy projects for support under various environmental regional and bilateral facilities. These facilities include GEF PIGGAREP and possibly bi-lateral export credits and grant components. They can assist with project preparation and compensate a developer for higher cost incurred by the use of a renewable source. Wind projects can claim contributions from the Prototype Carbon Fund (PCF) or other carbon trading facilities as their environmental benefits can be clearly demonstrated in diesel saving. The projects provide reductions in emissions when measured against a baseline output representing the situation “without” the project, i.e. diesel based generation. The output level of the baseline estimate is always dynamic and cannot be predicted exactly before the project’s implementation. The baseline for the projects discussed here can change significantly over their lives when the generation mix changes through development of sources other than diesel, i.e. wave energy or solar.

The dynamic changes of the baseline output over the project life represent an operational uncertainty that cannot be avoided. Other parameters that need to be considered when determining emission credits are the crediting times. Clearly, the longer the lifetime of a project the more credits can be claimed. Technical lifetime, commercial lifetime or the payback time of loans can be chosen to determine credits. In order to provide a first indication of potential emission reductions (metric tons of $CO_2$ saved), we have calculated emission reductions against the diesel baseline for the commercial lifetime of 20 years. At present, spot prices for carbon credits are in the range of Euro 20 per ton of $CO_2$ saved[15]. Trading volume is, however, still low in Europe and most credits are exchanged in long term contracts at significantly lower prices that suggested by the spot market. It is save to assume that for the time being prices will increase and not drop below NZ $ 15 per ton in the European market.

**Chart 5: Weekly CO2 Price Europe June 2005 – February 2006**



Source: http://www.pointcarbon.com/

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[15] Clearly the European market shows better prices than the US market.

## *7.2 Economic Analysis*

### Benefits Considered

A wind energy project for the Cook Islands has numerous benefits as described earlier. Apart from the partial displacement of diesel fuel required to generate electricity in Rarotonga, the benefits of energy diversification and supply security that wind technology will bring are highly significant (assuming that the recommended wind monitoring program confirms a viable wind resource in Rarotonga). Given the lack of a strategic fuel reserve in the Cooks, the power sector is highly vulnerable to international diesel fuel price volatility, which has been especially evident in the past two years, and to potential fuel supply disruptions. By reducing fuel throughput requirements, reliable wind-based generation will reduce this vulnerability to an extent and to a value that, while not readily quantifiable, is significant in our opinion. Wind technology will also have an environmental benefit (lower emissions and reduced risk of fuel mishaps due to lowered fuel throughput) as discussed in the UNDP/UNESCO report and the technical evaluation. They are however considered to be slight to the Cook Islands and they are not quantified here. The benefits may, however, have a higher (at least symbolic) value to the global community, as reflected in possible financial concessions, e.g., ‘carbon credits’, or grants available to the project from international agencies. On the other hand the unquantifiable energy diversification and supply security benefit somewhat lowers the ‘rejection threshold’ for raw economic performance of wind technology, as measured by the readily-quantifiable benefit of diesel fuel savings over the expected 20-year life of the optimum project.

The analysis presented here does not include a capacity benefit, i.e., it is not designed to displace diesel capacity requirements in the Rarotonga power system. This is a very conservative assumption if the system design includes a battery bank. While uncertainties surrounding the available wind resource in Rarotonga make any allowance for capacity requirements risky, the flow battery has a firm capacity of 200 KW for a maximum of 4 consecutive hours. This is allows the unit to reduce peak load (load shaving) and could be credited as economic benefits The 2 MW configuration of the proposed wind project is selected as optimum for Rarotonga, as it minimises technical control problems when connected to the existing diesel system in Rarotonga, as discussed in the technical evaluation.

### UNDP Proposal

The UNDP/UNESCO report contains an extensive economic analysis of the proposed project under three different financing scenarios including concessional (low interest) loans. The methodology employs a ‘levelized cost’ approach which compares the net present values of costs of (i) a diesel system alone and (ii) the hybrid wind-diesel power system as proposed, calculated using an 8% economic discount rate over 20 years. This approach is simple and concise, but being ‘static’ cannot take account of potentially important dynamic effects such as demand growth and long-term changes in real fuel prices. Also, the approach requires the selection of an economic discount rate, on which observers often disagree[16]. The evaluation below therefore replaces the levelized cost approach with a conventional analysis of

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[16] For years, there has been an active debate internationally with widely varying views about the ‘appropriate’ economic discount rate to apply to renewable energy projects. Different discount rates are valid for different participants in projects. The controversy is unlikely to be resolved in the present context.

the economic internal rate of return[17] (EIRR) of the proposed project, which is capable of modelling dynamic changes and does not require prior selection of a discount rate. Strictly real economic values are used (i.e., inflation and taxes and other financial effects are ignored). The analysis has been designed so that changes in load growth expectations, base fuel prices and expected real fuel price increases, and the effects of changing the wind system capital cost and energy delivered can be conveniently tested.

Below is a simple economic assessment of the proposed wind project, based on costs and quantifiable and unquantifiable benefits, from the perspective of the Cook Islands. This is followed by a brief discussion of financing options.

### The base case model

As a starting point for discussion of the economic performance of the proposed wind project, Table 7 presents the results of a basecase model which, with the exceptions of the base fuel price assumption, the explicit introduction of demand growth, and the delivered wind energy as discussed below, replicates the UNDP/UNESCO basecase (8-machine configuration without concessional financing) as closely as possible.

### Wind resource

Gross wind energy available (col 3) and gross wind surplus energy (col 4) and thus the net wind supply to load (col 5) have been reduced to from the UNDP/UNESCO report estimates in recognition that there is a significant risk, pending further monitoring, that the wind resource in Rarotonga has been overestimated. Gross wind energy is assumed to be 4000 MWh/a with an initial mis-match penalty of 5 % in year one. The mismatch penalty is reduced to zero over the project lifetime as demand grows and experience with the system is gained.

### Base fuel price

The recent study on petroleum supply for Cook Islands funded by ADB advises (2005) that the current economic price (i.e., net of taxes) of diesel fuel for generation in Rarotonga is NZ$1.02/litre, and this has been adopted as the base fuel price. The evaluation considers fuel prices ranging from $0.80/litre to $2.0/litre, and this range is tested and discussed below. Real fuel price escalation is assumed zero, as is implicit in all scenarios in the UNDP/UNESCO report. Increases in the range between 0.5 and 3.5 % p.a. are however tested.

### Rarotonga demand growth

Base year energy supply behind TAU busbar is assumed to be 26 GWh per annum. Long-term demand growth in Rarotonga is expected to average 3 percent per annum over the 20-year period, as discussed in the UNDP/UNESCO report. Variations in demand have only minor impacts on the economic performance of the project.

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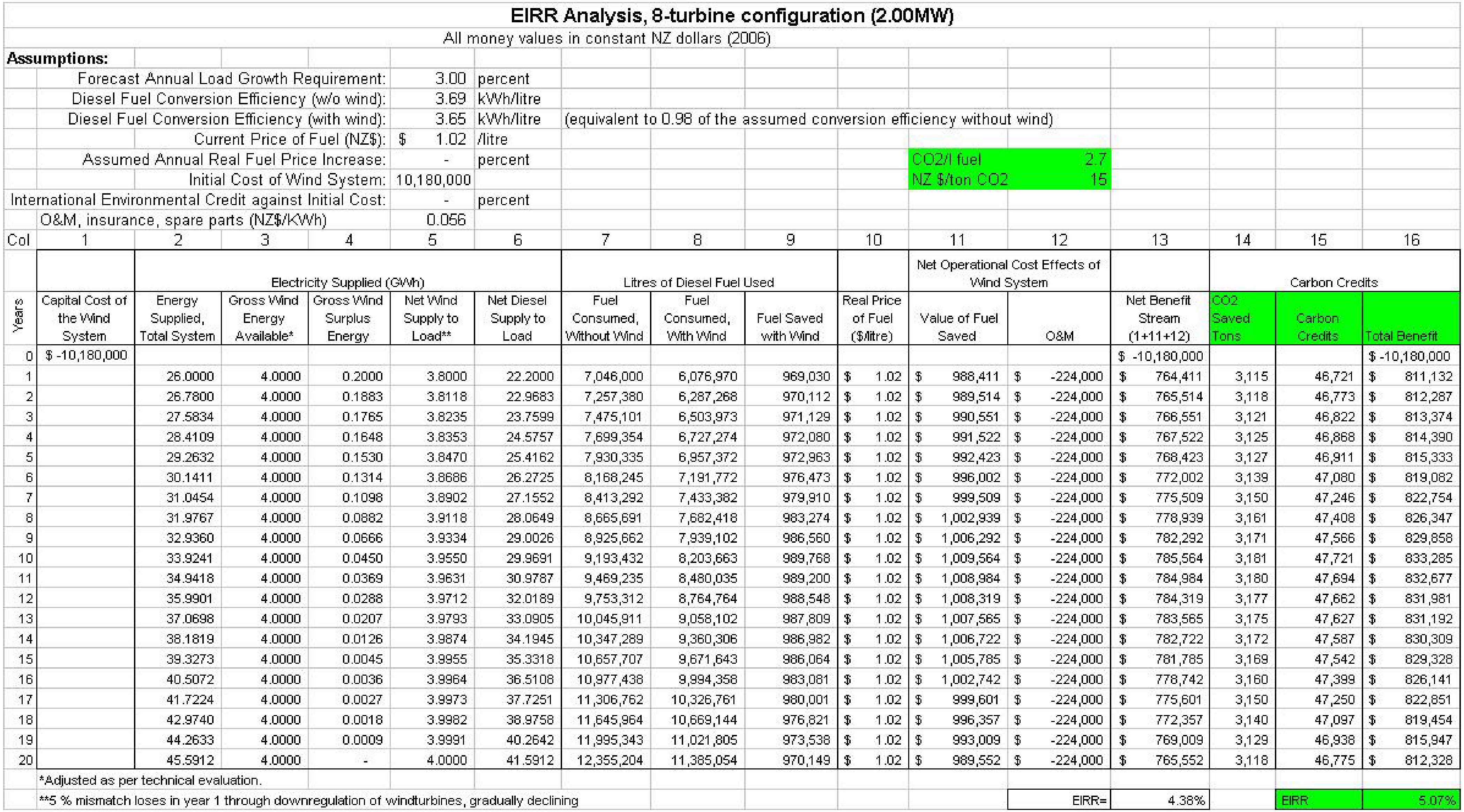
[17] The economic internal rate of return (EIRR) is the discount rate, calculated from a comparison of the initial economic cost of a project to the stream of future economic benefits, at which the net present value of the project is zero. As a discount rate, the EIRR is expressed as a percentage. The higher the EIRR, the higher is the intrinsic economic value of the project to the country.

**Table 7: ‘Basecase’ Model**



### EIRR Analysis, 8-turbine configuration (2.00MW)

All money values in constant NZ dollars (2006)

**Assumptions:**

Forecast Annual Load Growth Requirement: 3.00 percent
Diesel Fuel Conversion Efficiency (w/o wind): 3.69 kWh/litre
Diesel Fuel Conversion Efficiency (with wind): 3.65 kWh/litre (equivalent to 0.98 of the assumed conversion efficiency without wind)
Current Price of Fuel (NZ$): $ 1.02 /litre
Assumed Annual Real Fuel Price Increase: - percent
Initial Cost of Wind System: 10,180,000
International Environmental Credit against Initial Cost: - percent
O&M, insurance, spare parts (NZ$/KWh) 0.056

CO2/l fuel 2.7
NZ $/ton CO2 15

| Col | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Electricity Supplied (GWh) | | | | | Litres of Diesel Fuel Used | | | | Net Operational Cost Effects of Wind System | | | Carbon Credits | | |
| Years | Capital Cost of the Wind System | Energy Supplied, Total System | Gross Wind Energy Available* | Gross Wind Surplus Energy | Net Wind Supply to Load** | Net Diesel Supply to Load | Fuel Consumed, Without Wind | Fuel Consumed, With Wind | Fuel Saved with Wind | Real Price of Fuel ($/litre) | Value of Fuel Saved | O&M | Net Benefit Stream (1+11+12) | CO2 Saved Tons | Carbon Credits | Total Benefit |
| 0 | $ -10,180,000 | | | | | | | | | | | | $ -10,180,000 | | | $ -10,180,000 |
| 1 | | 26.0000 | 4.0000 | 0.2000 | 3.8000 | 22.2000 | 7,046,000 | 6,076,970 | 969,030 | $ 1.02 | $ 988,411 | $ -224,000 | $ 764,411 | 3,115 | 46,721 | $ 811,132 |
| 2 | | 26.7800 | 4.0000 | 0.1883 | 3.8118 | 22.9683 | 7,257,380 | 6,287,268 | 970,112 | $ 1.02 | $ 989,514 | $ -224,000 | $ 765,514 | 3,118 | 46,773 | $ 812,287 |
| 3 | | 27.5834 | 4.0000 | 0.1765 | 3.8235 | 23.7599 | 7,475,101 | 6,503,973 | 971,129 | $ 1.02 | $ 990,551 | $ -224,000 | $ 766,551 | 3,121 | 46,822 | $ 813,374 |
| 4 | | 28.4109 | 4.0000 | 0.1648 | 3.8353 | 24.5757 | 7,699,354 | 6,727,274 | 972,080 | $ 1.02 | $ 991,522 | $ -224,000 | $ 767,522 | 3,125 | 46,868 | $ 814,390 |
| 5 | | 29.2632 | 4.0000 | 0.1530 | 3.8470 | 25.4162 | 7,930,335 | 6,957,372 | 972,963 | $ 1.02 | $ 992,423 | $ -224,000 | $ 768,423 | 3,127 | 46,911 | $ 815,333 |
| 6 | | 30.1411 | 4.0000 | 0.1314 | 3.8686 | 26.2725 | 8,168,245 | 7,191,772 | 976,473 | $ 1.02 | $ 996,002 | $ -224,000 | $ 772,002 | 3,139 | 47,080 | $ 819,082 |
| 7 | | 31.0454 | 4.0000 | 0.1098 | 3.8902 | 27.1552 | 8,413,292 | 7,433,382 | 979,910 | $ 1.02 | $ 999,509 | $ -224,000 | $ 775,509 | 3,150 | 47,246 | $ 822,754 |
| 8 | | 31.9767 | 4.0000 | 0.0882 | 3.9118 | 28.0649 | 8,665,691 | 7,682,418 | 983,274 | $ 1.02 | $ 1,002,939 | $ -224,000 | $ 778,939 | 3,161 | 47,408 | $ 826,347 |
| 9 | | 32.9360 | 4.0000 | 0.0666 | 3.9334 | 29.0026 | 8,925,662 | 7,939,102 | 986,560 | $ 1.02 | $ 1,006,292 | $ -224,000 | $ 782,292 | 3,171 | 47,566 | $ 829,858 |
| 10 | | 33.9241 | 4.0000 | 0.0450 | 3.9550 | 29.9691 | 9,193,432 | 8,203,663 | 989,768 | $ 1.02 | $ 1,009,564 | $ -224,000 | $ 785,564 | 3,181 | 47,721 | $ 833,285 |
| 11 | | 34.9418 | 4.0000 | 0.0369 | 3.9631 | 30.9787 | 9,469,235 | 8,480,035 | 989,200 | $ 1.02 | $ 1,008,984 | $ -224,000 | $ 784,984 | 3,180 | 47,694 | $ 832,677 |
| 12 | | 35.9901 | 4.0000 | 0.0288 | 3.9712 | 32.0189 | 9,753,312 | 8,764,764 | 988,548 | $ 1.02 | $ 1,008,319 | $ -224,000 | $ 784,319 | 3,177 | 47,662 | $ 831,981 |
| 13 | | 37.0698 | 4.0000 | 0.0207 | 3.9793 | 33.0905 | 10,045,911 | 9,058,102 | 987,809 | $ 1.02 | $ 1,007,565 | $ -224,000 | $ 783,565 | 3,175 | 47,627 | $ 831,192 |
| 14 | | 38.1819 | 4.0000 | 0.0126 | 3.9874 | 34.1945 | 10,347,289 | 9,360,306 | 986,982 | $ 1.02 | $ 1,006,722 | $ -224,000 | $ 782,722 | 3,172 | 47,587 | $ 830,309 |
| 15 | | 39.3273 | 4.0000 | 0.0045 | 3.9955 | 35.3318 | 10,657,707 | 9,671,643 | 986,064 | $ 1.02 | $ 1,005,785 | $ -224,000 | $ 781,785 | 3,169 | 47,542 | $ 829,328 |
| 16 | | 40.5072 | 4.0000 | 0.0036 | 3.9964 | 36.5108 | 10,977,438 | 9,994,358 | 983,081 | $ 1.02 | $ 1,002,742 | $ -224,000 | $ 778,742 | 3,160 | 47,399 | $ 826,141 |
| 17 | | 41.7224 | 4.0000 | 0.0027 | 3.9973 | 37.7251 | 11,306,762 | 10,326,761 | 980,001 | $ 1.02 | $ 999,601 | $ -224,000 | $ 775,601 | 3,150 | 47,250 | $ 822,851 |
| 18 | | 42.9740 | 4.0000 | 0.0018 | 3.9982 | 38.9758 | 11,645,964 | 10,669,144 | 976,821 | $ 1.02 | $ 996,357 | $ -224,000 | $ 772,357 | 3,140 | 47,097 | $ 819,454 |
| 19 | | 44.2633 | 4.0000 | 0.0009 | 3.9991 | 40.2642 | 11,995,343 | 11,021,805 | 973,538 | $ 1.02 | $ 993,009 | $ -224,000 | $ 769,009 | 3,129 | 46,938 | $ 815,947 |
| 20 | | 45.5912 | 4.0000 | - | 4.0000 | 41.5912 | 12,355,204 | 11,385,054 | 970,149 | $ 1.02 | $ 989,552 | $ -224,000 | $ 765,552 | 3,118 | 46,775 | $ 812,328 |
| | | | | | | | | | | | | EIRR= | 4.38% | | EIRR | 5.07% |

*Adjusted as per technical evaluation.

**5 % mismatch loses in year 1 through downregulation of windturbines, gradually declining

### Fuel conversion efficiency

The basecase above adopts the UNDP/UNESCO report's assumptions about the rate of diesel fuel conversion efficiency as measured by electrical energy supplied at the busbar (i.e., after accounting for power station own consumption), or 0.271 litres/kWh (3.69 kWh/litre) in the Rarotonga power system before wind is introduced. The UNDP/UNESCO report allows for a 3 percent degrading of fuel conversion efficiency after wind is installed, to account for higher spinning reserve requirements. Though apparently slight, this degrading has a relatively heavy depressing effect on the EIRR value under conditions of increasing demand, since the degraded diesel performance applies to the entire diesel output (which is growing in step with load growth) but is attributable to the introduction of wind and represents an economic cost.

The 3-percent efficiency 'penalty' rate is likely to be significantly less if an active storage system with a programmable control unit is used as proposed here. The penalty will also decrease over time after wind is introduced, as Rarotonga's power system operators gain more experience in finetuning wind and diesel energy inputs to the system. The base case above therefore adopts a 1 percent post-wind installation efficiency penalty rate as an average over the 20-year period. Nevertheless, even the 1-percent penalty is significant, reducing potential diesel fuel savings due to the wind project by about 1.7 million litres over the life of the project. As modelled, annual fuel savings rise in the years following installation of wind, as wind 'surplus energy' is gradually absorbed into the power system, but after year 10 fuel savings decline progressively as an increasing proportion of total load is supplied by diesel, as illustrated in the charts below.

## *7.3 International environmental financial credits*

Though the direct environmental benefit to the Cook Islands of the proposed wind project are real (reduced atmospheric pollution and reduced risk of fuel or lubricant spillage due to the partial displacement of diesel power), they are considered slight and are not quantified or considered further in this analysis. However, the environmental significance of the project to the international community may well exceed its direct environmental impact in the Cook Islands. Under the umbrella of international climate protection protocols, various financial mechanisms are emerging which are designed to encourage countries to reduce atmospheric emissions of greenhouse gases from the burning of fossil fuels. These mechanisms are recent, are not fully designed or implemented, and have not been universally ratified, but are reflective of the international community's desire to find viable means to reduce fossil fuel consumption through both conventional energy conservation and displacement by renewable energy, including wind. Successful renewable energy demonstration projects that might be replicated by other countries play a key role in global strategies to accomplish this. The proposed wind energy project in the Cook Islands, assuming the wind resource proves to be viable and the project performs as expected, will have a high international profile and, as indicated in the UNDP/UNESCO report, will be designed for ease of replication by other island countries in the Pacific and elsewhere.

Under these circumstances, it is reasonable to expect that a well-designed wind energy project in the Cook Islands will be eligible for environment-related financial assistance, possibly in the form of 'carbon credits' as discussed in the technical evaluation or grant assistance from the European Union Energy Facility or bilateral donors on the strength of the project's demonstration potential. In the base case model, however, international financial grants against initial cost are assumed to be zero. Table 7 above shows an alternative to the base case, which is a base case plus carbon credits. Carbon credits are conservatibvely estimated at NZ$ 15 per ton of $CO_{2.}$ This increases the base case EIRR to

### 7.4 Criteria for project selection

The EIRR is a comparative measure of the economic worth of allocating resources to alternative projects, or to the same project under alternative conditions. In the commercial environment that many power utilities (including TAU and other Pacific island utilities) operate in, a properly-assessed EIRR of a project of at least 8%-12% is usually required before investment in the project from national or utility resources is approved. For example, the power utility in Papua New Guinea has adopted a minimum 10% rate of return rule for internally-financed power projects; the Asian Development Bank generally applies a 12% minimum rate of return rule to economic and social development projects before approving loan finance. The UNDP/UNESCO report evaluates the present value of costs using an 8 percent discount rate, and we adopt the same rate as the economic criterion for selecting and implementing the proposed wind project, subject to the discussion below.

Under the above parameters, the 'basecase' model shows that the economic internal rate of return of the proposed wind project is 4.4 percent. This indicates that, purely in terms of global resource allocations (capital cost vs diesel fuel and other operational savings), the project is not a worthwhile economic investment. However, in the Cook Islands, the project represents more than a means to improve global energy resource allocations; as discussed above, a significant benefit is diversification of energy sources for power generation in Rarotonga (eliminating sole dependency on imported diesel fuel) and the reduction in vulnerability to supply disruptions that diversification implies. It is of course very difficult to put a resource value on this benefit, and any attempt to do so is necessarily subjective. In the authors' opinion, the benefit of energy diversification is significant, worth perhaps the equivalent of a 3 percent rate of return in conventional resource savings. If accepted, this value implies that the EIRR achieved in the base case is 7.4 per cent. We recommend here to use a 10 percent threshold that needs to be achieved for TAU and the CI Government to accept a project.

### 7.5 Expected economic performance of the wind project

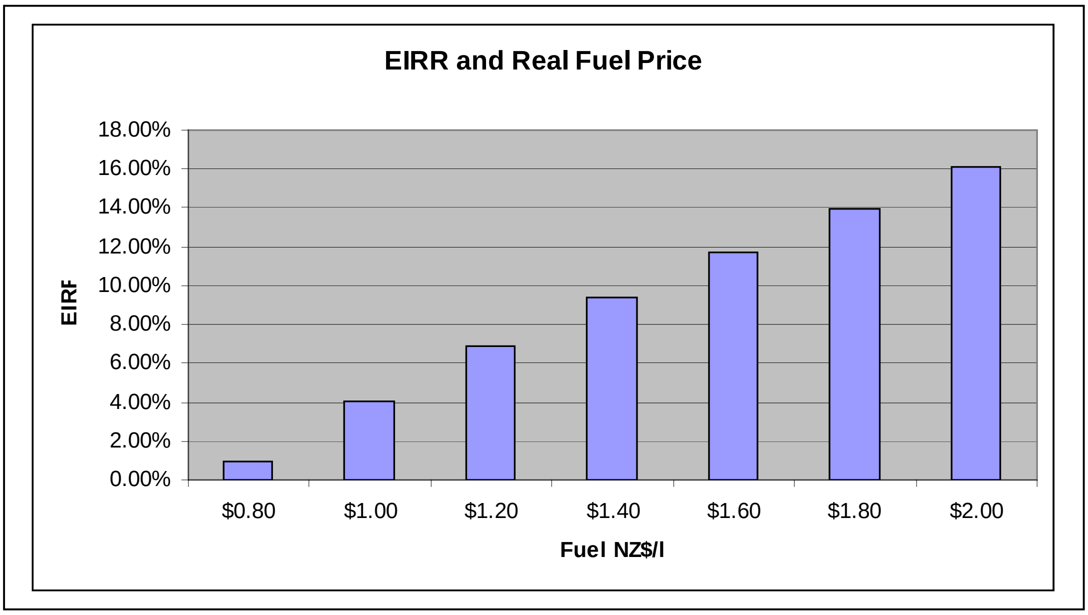
Reasonable assumptions about the economic performance of the proposed wind project from the perspective of the Cook Islands can differ widely, because three fundamental parameters are largely unknown: (i) the appropriate base price of fuel (unknown because international fuel prices are highly volatile, and the Cook Islands government lacks any means to control them); (ii) the long term average rate of real increase in fuel prices (unknown for similar reasons); and (iii) the degree of availability of international financial credits against the initial cost of a wind system installed in the Cook Islands (uncertain because proposed international financing mechanisms for energy projects that mitigate greenhouse gas emissions are currently developing). There is also uncertainty with respect to the wind resource, this however can be removed by on site wind measurements

Under the basecase parameters, the wind project shows an EIRR of 4.4 percent, well below our selection criterion of 10 percent. However, the actual economic performance of the project will depend to an important degree on the actual behaviour of the three unknown parameters. In the balance of this section, we discuss the sensitivity of the economic returns of the project (from the perspective of the Cook Islands) to variations in the three unknowns, and whether the 5 percent criterion can be reached within reasonable variations of them.

### 7.6 *The base price of fuel*

In light of the recent volatility of fuel prices, the appropriate base price of fuel to use in this type of analysis may include a wide range. The 2005 price of $1.02/litre appears to be a reasonable value for economic analysis of the wind project. Nevertheless, there is certainly precedent for wide swings in fuel prices in the short term. Chart 6 shows the effect on EIRR of variations in the base fuel price assumption.

**Chart 6**



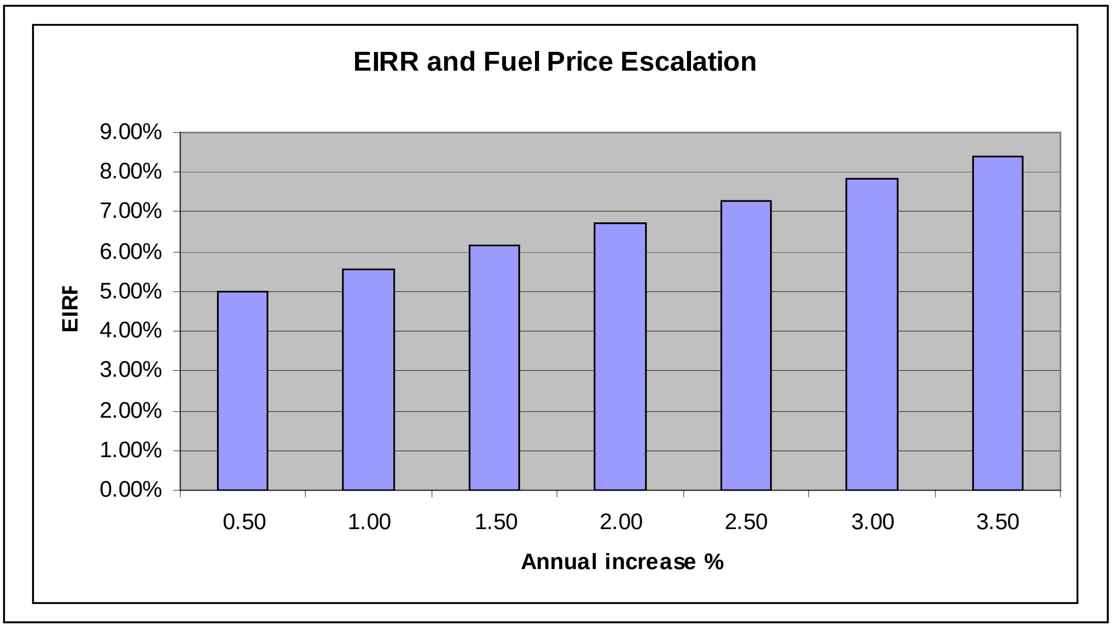
The base fuel price required to reach an EIRR of 10 percent is $1.40/litre, when other variable parameters in the base case model are held constant. Since this price significantly exceeds the current and historical yearly average fuel prices, and is near the top of the range of historical short-term fluctuations, it is not considered to be a reasonable value for the base fuel price for this economic evaluation.

### 7.7 *The real rate of fuel price escalation*

In light of the gradual depletion of fossil fuel reserves, which with certainty will occur in the future, and the likelihood of international supply disruptions due to political unrest and war, it may be expected that the real price of fossil fuels will eventually continue to rise in the future, although real fuel prices have historically fallen. The timing and magnitude of real fuel price increases are highly uncertain.

With a base fuel price of $1.02/litre, the effect of variations in the real fuel price escalation assumption (zero in the base case model) is shown in Chart 7. Accordingly a 3 % annual increase in fuel price would increase the EIRR to approx 8 %.

**Chart 7**



This rate greatly exceeds historical precedent and does not appear to be a reasonable assumption for future sustained real price increases within the project period. We therefore adopt the UNDP/UNESCO report's assumption of a zero percent average real rate of fuel price increase.

### *7.8 The availability of international environmental financial credits against initial cost*

The initial cost of the proposed wind project is estimated at NZ$10,2 million. Unless investment cost can be dropped through competitive bidding and or higher wind potential can be confirmed through on site measurements, it is obvious that the project will require concessional or part-grant financing from the international community in order to become economically attractive in the perspective of the Cook Islands. As discussed previously, the project is likely to be eligible for environment-related international credits, either in the form of 'carbon credits' or on the basis of the project's value as an international demonstration of wind energy in a small-island setting, or both. In this section we examine the degree of concessional finance, measured as the percent of grant-aid contribution against the initial cost of $10.2 million, required to reach the minimum criterion EIRR of 10 percent.

Chart 8 shows the effect of varying the level of grant aid against the $10.2 million initial cost of the proposed wind project. When other cost parameters of the base case model are held constant, the criterion EIRR of 10 percent for the wind project is reached when about 35 percent of the initial cost or about is provided by the international community, effectively reducing the initial cost in the Cook Islands to $6.6 million. This level of financial contribution, is not likely to be available through carbon credits, but may be through sources such the EU Energy Facility or grant aid under EDF 10[18]. Chart 8 shows the EIRR at various levels of grant financing, Chart 9 shows the impact of carbon credits.

**Chart 8**

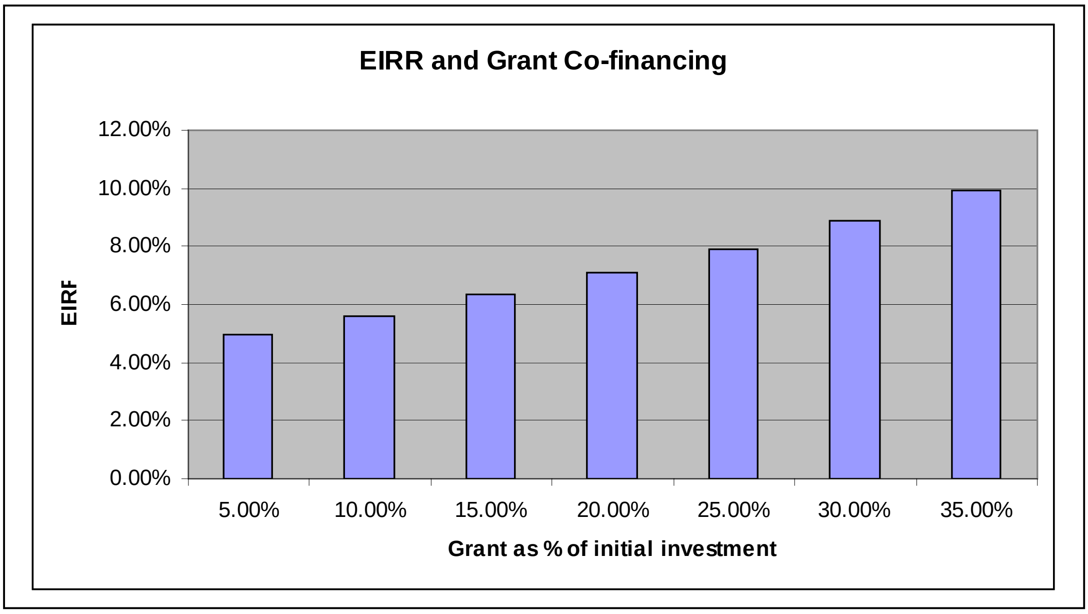
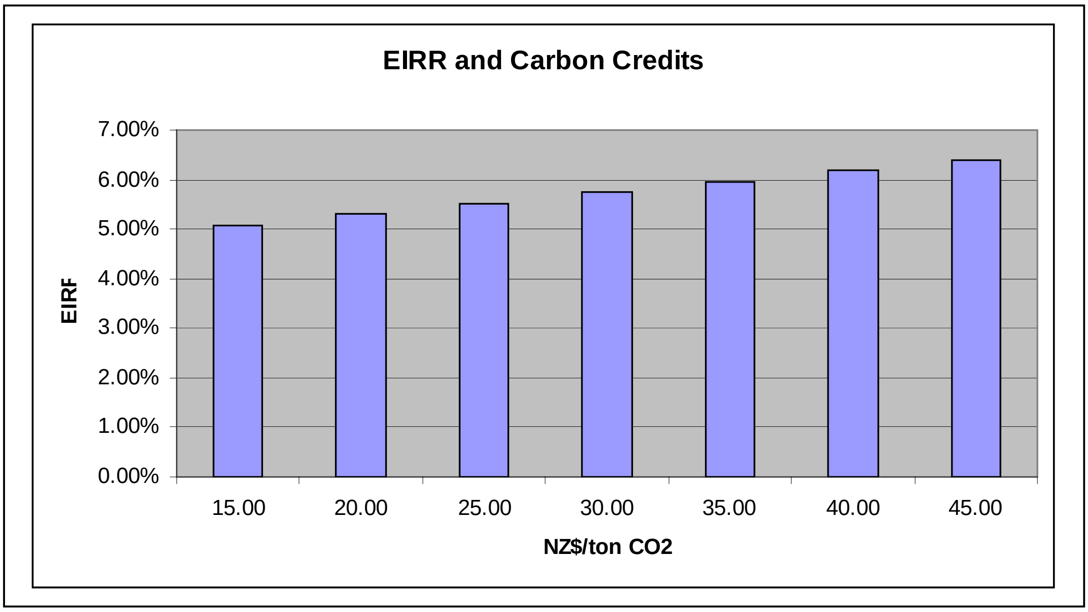


**Chart 9**



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[18] A preliminary discussion on the issue was held with the Head of the EU Delegation for the Pacific who indicated that in principle a wind energy project would be eligible for EDF 10 or EU Energy Facility co-funding.

### *7.9 Conclusions about the expected economic performance*

The more important parameters are those examined previously, i.e., the base fuel price, the real annual rate of fuel price increases, and the capital cost of the wind project after allowing for the project's eligibility for international environmental credits. Of these, we consider that the base case model assumptions for the base fuel price (NZ$1.02/litre) and real rate of fuel price increases (zero percent per annum) are conservative and adequate for planning purposes.

The last parameter, capital cost, is the most important of the three, as (at least to some extent) it can be addressed through project preparation including properly-prepared applications for external environment-related financial contributions. The above analysis indicates that the wind project requires an external capital subsidy of about 35 percent of the estimated initial cost of NZ$10.2 million (i.e., about NZ$3.6 million or Euro 2 million) before it is an economically viable investment in the Cook Islands. On the basis of the cost and energy output potential of the wind project as known to date, the selected wind project developer, in collaboration with the government, will need to secure external funding in roughly the above amount.

We recommend that the wind project developer be selected through an international competitive bidding process. The winning bid will be selected on the bases of the offered selling price of electricity from the wind project to the Rarotonga power system and the financial soundness and corporate background of the developer. The bid price and the financial soundness of the developer will provide the ultimate indicators of the economic viability of grid-connected wind energy in Rarotonga.

## 8.0 ENVIRONMENTAL ANALYSIS

### *8.1 Introduction*

Wind turbines are powered by a 100 percent renewable resource and the only pollution is related to the relatively minor quantity of lubricants and hydraulic fluids that need changed at regular intervals. The minimal waste products may be mixed with diesel fuel and utilised in a conventional boiler or similar. One interesting fact about modern utility scale wind turbines is that the energy that goes into manufacturing the turbine is returned during the first 2 to 4 months of operation, depending on the wind resource.

### *8.2 The Wind Farm*

The greatest physical change imposed by the introduction of the wind energy plant is the wind turbines themselves. At approx. 30 – 50 meter hub height and approx. 30 meter rotor diameter, the wind turbines are clearly visible. The footprint of each turbine is a circular diameter of only approx. 2.5 meters, and the surrounding land remains basically undisturbed. The terrace required is approx 8000m2 per turbine. At a distance of 200 meters, the noise emission level is barely audible at 45 dB(A). During the installation of the foundations and the equipment itself, the soil will temporarily be disturbed, but it will be brought back to its natural condition upon completion of the project.

#### Access Road

Besides the foundation for the wind turbines the only permanent mark left on the ground will be the construction of a 4 m wide gravel road for construction and service access to the turbines. The access road shall have a maximum inclination of 1:8 (12.5%) and an axle bearing capacity of minimum 15 tonnes.

**Transformer**

There will be installed a 300 kVA, 0.415/11 kV, Y/Y or Y/∇ configured transformer adjacent to each wind turbine. Each transformer will have a footprint of approximately 1.5 meter x 2 meters (5 ft x 6.5 ft) and we recommend that the enclosure is ordered in a dark green colour that blends well with the ground vegetation.

Each wind turbine produces three-phase power at 415 volts to the transformer at the base of the tower. The transformer steps this voltage level up to the 11 kV grid distribution voltage and the power is transferred underground through cables to the existing power line nearest the site.

### *8.3 Noise Level of Wind Turbines*

Due to the strict noise emission requirements in the relatively densely populated European wind turbine market, wind turbines are designed with emphasis on low noise emission. At 7 m/s wind speed and standard rpm rotor speed, a turbine emits a sound power level of approx. 98 dB(A), at a measurement accuracy of +/- 2 dB. At a distance of 200 meters, the noise level is 45 dB(A). At lower wind speeds the noise emission is reduced and at higher wind speeds, the increasing ambient noise level from the wind masks the noise emission. Worldwide, 45 dB(A) is becoming the accepted noise tolerance level at private residences. At the proposed wind farm site the turbine setback is well within the commonly accepted guidelines at a distance of minimum 300 meters between the closest residence and wind turbine.

### *8.4 Other Environmental Considerations*

Meetings by the UNDP team with radio, TV and Civil Aviation representatives have confirmed that no negative impact is to be expected on these services.

The aesthetic impact of a wind turbine is of course an individual matter and is difficult to qualify. In general, wind turbines are designed with several features to minimise its visual impact and please the observer. The entire wind turbine, including the rotor, shall be coated with a discrete white/light grey finish with an anti-reflection coating for elimination of strobe effects from the sun.

At times avian mortality has been voiced as a concern in relation to wind farms. Research has documented that a wind turbine with a relatively slow spinning rotor and utilising a tubular tower with no features for perching poses *no* greater threat to birds than a power pole, antenna tower, or any other type of tall structure.

**Installation**

Wind technology is environmentally friendly, but care has to be taken to avoid negative environmental impacts during installation. When delivering 8 or more large wind generators to the installation site, a huge amount of material must be transported. Besides towers, blades and nacelles, there are the various components that go into the finished wind turbine. All of this must be carefully packaged to protect the machinery during transportation and handling.

This generates a pile of discarded packaging, boxes, plastic bags, Styrofoam and various other materials. These can be difficult to control since wind farms are located in windy locations. After installation there will be additional garbage such as containers used tools, pieces of metal, cables, etc. Provision has to be made to orderly dispose off all these materials in order to avoid negative environmental impacts of installation.

**Greenhouse Gas Mitigation**

In the operational stage the wind turbines will have a positive effect on the environment because it will replace diesel generation and thereby reduce the emissions of $SO_2$, $NO_x$ particles and $CO_2$.

A full Environment Impact Assessment (EIA) is required by the Government of the Cook Islands for a project of this magnitude, but preliminary on-site assessment by the Environment Service, Government of the Cook Islands have not identified any environmental issues that would hinder installation of wind turbines on any of the proposed site C. Upon receipt of the EIA report, the Environment Service will advertise and invite public comments on the project. Comments are only received within 30 days of advertising. Thereafter the project is presented along with the comments for the Environment Council's consideration and approval.

# 9.0 Risk management, institutional arrangements and implementation modality

## *9.1 Risk analysis*

Maturity of technology, long operating experience and suppliers' warrantees do not mean that the proposed projects do not carry considerable risk. For TAU and the Government of the Cook Islands, the projects represent a substantial investment and responsibility to manage and mitigate project risks. The risks involved in sponsoring a wind power project are different in character and more difficult to manage than those encountered in diesel projects. While diesel projects have relatively modest front-end development risks, they are exposed to fuel supply problems, changes in fuel prices and other plant related operation and maintenance problems. The greatest risk wind energy has is related to the resource and involves risks both in the construction and the operation phase. To a degree when allocating wind resource risk, distinguishing the four categories of risk helps to facilitate the exercise:

- Hurricane damage during construction
- Short-term shortfalls in mean energy flows
- Catastrophic failure in operation due to hurricane
- Long-term sustained energy deficits

Although a sound assessment of a project's wind regime usually helps to reduce uncertainty, these assessments will always rely on statistical analysis that assumes that historic flow patterns will continue in the future. Unfortunately, there is an appreciable margin for error demonstrated empirically in a number of existing wind power projects. TAU has suggested considering a scaled-down pilot or demonstration project that could be expanded if operational experience proves that the technology is viable. This would result in a higher specific energy production cost and is not recommended.

### Minimizing TAU’s Risk

In allocating risks, we adopt the guiding principle that a party bears the risk if it is best able to minimise, manage, control or bear the risk or is the party that receives the greater economic benefit of running the risk. It is consistent with these principles that the party responsible for designing and operating the project and undertaking the meteorological and geological investigations and studies is in a better position to minimise, manage and control the risk and should therefore assume the major risk burden in these areas.

As neither TAU nor the government of the Cook Islands is in a good position to manage resource-and technology-related risks, a BOT-type scheme should be considered. As we expect that there are at least two potential bidders[19] and more will undoubtedly be attracted, the government of the Cook Islands is in a good position to pursue international competitive bidding for the project.

The BOOT modality (Built Own Operate Transfer) is the most common modality for private participation in power projects but other modalities have been proposed from time-to-time including Build-Transfer-Lease (BTL), Build-Transfer (BT) and Build-Own-Operate (BOO). BOOT or BOO seems preferable in this case as ownership and operation of the project by the sponsor ensures complete commitment to the project’s commercial success. Transfer of title to wind power projects to the Government after a reasonable operating period[20] is desirable but not necessary. The technology has a long but definite economic live and a transfer may not be favored as O&M cost will significantly increase towards the end of the economic life.

The following table exhibits a risk allocation matrix that could be applied to a BOO/BOOT project. For the sake of analytical clarity, risks are distinguished between construction and operating phases and are allocated between the Government, TAU, an EPC contractor, the investor/sponsor, lenders, and an operator. In reality, one party can assume various roles (the investor can also be the operator and perhaps even the EPC contractor).

As the table shows, the Government basically holds sovereign risk (regulatory changes for which the Government is responsible) and the payment risk: in case TAU fails to meet its payment obligations under a power purchase agreement (PPA), the government has to step in, possibly supported by a guarantee provided by a Multilateral Lending Agency (MLA). TAU would have to guarantee a minimum payment to the private sector operator (independent power producer (IPP)) in order to guarantee debt service. That is, the risk of serious shortfalls in wind energy supply would have to be shared between the investor and TAU as the off-taker. This is considered a necessity if some form of commercial finance is used for the project.

Confident investors, who carry out their own wind measurements perhaps backed by a hardware supplier who is sure that the wind regime will be sufficient to supply energy to meet debt service could waive this provision and gain a considerable competitive edge in international competitive bidding. All other technology-related risks during construction and operation would rest with the investors, their lenders

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[19] The UNDP/UNESCO proposal recommends that TAU implements the project, but does not exclude a BOT modatility.

[20] For wind power projects, an operating concession of between 15 and 20 years is normally sufficient for a reasonable return on invested money to be earned.

and the EPC and Operations contractors. If the BOOT route is chosen, provisions should be made to train TAU staff in all required O&M work before the transfer date.

This approach can be tested in the market to ensure that TAU gets a project that it can afford. TAU would only accept a bid that would offer energy at a tariff that is below its own anticipated generation cost.

The government could promote an IPP program to attract private investors to invest in wind and other renewable energy projects.  Promotional efforts can be made by the Government and TAU including:

a) Dissemination of relevant information both nationally and internationally
b) Establishing transparency of procedures
c) Encouraging public participation
d) Facilitation of access to financing
e) Facilitation of joint ventures and cooperation between foreign and local partners

These measures could be undertaken immediately.  If private investment is to play a role in the development of wind energy projects in the Cook Islands, the institutional process must be sympathetic to the needs of investors, lenders and power purchasers. Active and optimum participation of the private sector in renewable energy development requires:

- A suitable legal, regulatory and institutional framework;
- A power purchase agreement (PPA) that is tailored to the needs of the parties to small power projects and that reflects the capabilities of the country's judicial system
- Tariff determination that encourages projects that best meet the commercial, technical, economic and environmental objectives of the buyer and of the government.

***Table 8a: Risk Assignment Table for Case Study Project Pre-Operation Phases***

| *TYPE OF RISK* | *EVENT* | *RISK MANAGEMENT* | *RISK ASSIGNMENT* |
|---|---|---|---|
| ***Sovereign/ Political Risk***<br>*(Also applicable for Operation Phase )* | • Regulatory Changes | • Change-in-law and Extension of Time clauses in PPA, EPC contract | • Government backed by MLA guarantee |
| | | • Government guarantee | |
| | | • Political risk insurance or MLA partial risk guarantee | |
| | • Inadequate Contract Enforcement | • Transparent, independent dispute resolution procedures | • Government |
| | | • Sound legal, regulatory & institutional framework | |
| | • Economic Problems (e.g. high inflation, currency realignments) | • Rise and fall and foreign exchange adjustment formulas in EPC contracts | • Investor |
| | | • Hedging of EPC costs with financial instruments | |
| ***Completion Risk*** | • Non-Political Force Majeure (e.g. major hurricane, earthquake) | • Force Majeure clauses in concession, off-take and O&M agreements | • Investor backed by insurance |
| | | • Insure against insurable non-political Force Majeure events | |
| | • Unforeseen Conditions and related cost and time overruns on EPC contract | • Thorough site investigations and geotechnical studies | • Investor, possibly relieved through back to back conditions in EPC contract and PPA |
| | | • Transfer risk to EPC contractors through contractual remedies:<br>- Fixed price/date EPC contract.<br>- Back-to-back liquidated damages in project contracts | |
| | | • Transfer risk to TAU through off-take price adjustment and extension of time clauses in PPA | |
| | | • Good quality EIA, Action Plans and Management Plans | |
| | • Cost and Time Overrun on EPC Contract not related to unforeseen conditions | • Contingency finance measures:<br>- emergency equity<br>- stand-by finance | EPC Contractor |
| | | • Contractual remedies:<br>- Fixed price/date EPC contract<br>- Back-to-back liquidated damages in project contracts | |
| | • Environmental Impacts | • Environmental obligations and constraints specified in Project Agreements<br>• Performance damages in Project Agreements | • Government for quality of studies<br>• Investor for implementation of obligations defined |

***Table 8b:*** ***Risk Assignment Table for Case Study Project Operation and Transfer Phases***

| *TYPE OF RISK* | *EVENT* | *RISK MANAGEMENT* | *RISK ASSIGNMENT* |
|---|---|---|---|
| ***Resource Risk*** | • Long term Shortfall in wind energy production | • Quality meteorological analysis using reliable data and independent checking | • Investor up to shortfall in debt service and after debt service period<br>• Debt service guaranteed by TAU through minimum payment clause in power purchase agreement |
| | | • Adjustment to PPA terms to compensate for long term wind energy variances | |
| | | • Minimum payment to guarantee debt service | |
| | • Short term variations in wind energy production | • Optimize plants to minimize surplus energy | |
| | | • Minimum payment to guarantee debt service | |
| | | • Adjustment to PPA terms to compensate for annual wind energy variances | |
| ***Operating Risk*** | • Non-political Force Majeure (hurricane, earthquake, land slide, etc.) | • Force Majeure clauses in PPA and O&M agreements. | • Investor backed by insurance |
| | | • Insure against insurable non-political Force Majeure events | |
| | • Interruptions due to O&M Problems | • Employ an experienced and reputable O&M contractor | • Investor/ Owner |
| | | • Include design safeguards to reduce plant and transmission line outages | |
| | | • O&M agreement to specify high maintenance standards | |
| | | • Liquidated damages remedies | • O&M Contractor |
| ***Commercial Risk*** | • Reduced demand | • Tariff structure to secure debt service revenues (e.g. “take-or-pay” charge) | • Investor up to shortfall in debt service and after debt service period<br>• Debt service guaranteed by Off-Taker through a minimum payment clause in power purchase agreement |
| | • Conflict over dispatch due to low diesel price | • Minimum payment mechanism (Take-or-Pay charge) | |
| | • Insolvency of Project Co. | • Default, termination and disposal of assets clauses in Project Agreements | • Investor up to equity and lenders for outstanding debt |
| | | • Collateral Arrangements | |
| | • Inability of TAU to make payment | • Government guarantee of TAU obligations (including payment). | • Government backed by MLA partial risk guarantee for debt service Government by sovereign guarantee for residual risk beyond debt service |
| | | • MLA partial risk guarantee to secure debt service payments | |

### Risk Management through competitive bidding

One-stage competitive bidding is recommended to determine a tariff. The RFP package should essentially consist of a Power Purchase Agreement in which the energy tariff is left open and the minimum diesel setting and perhaps the maximum capacity of the wind project are specified. The PPA would then essentially be a take or pay arrangement where TAU commits to purchase all energy up to system load that is available above the minimum diesel setting.

It would be up to TAU to determine its avoided cost as a benchmark and consider how much energy it wants to purchase in an average year. If TAU assumed a comparatively low future diesel price as a decision point, it would be on the safe side in terms of financial risk. Structuring finance would be left to the private sector investor who would have to explore concessionary finance through IFC, GEF, the Prototype Carbon Fund, Export Credit Agencies and other sources. The RFP package would have to be of sufficient quality to enable investors to perform this task. It is therefore recommended that the government seek technical assistance support for the preparation of the PPA and the RFP. Possible sources of such assistance are PIEPSAP, the World Bank-operated PPIAF (Private Participation in Infrastructure Advisory Facility), GEF or bilateral aid programs.

It should be noted that the majority of BOOT power project concessions have been awarded through direct negotiation between the Government and a prospective sponsor following an unsolicited approach. International experience has exposed serious weaknesses in this approach. Direct negotiation of non-competitive bids has conspicuously failed to meet the objectives of governments, investors and power utilities. Problems encountered with this model include the following:

***In the absence of competition, there is no assurance that agreed prices are fair or reasonable.*** If a party to a negotiation is not adequately represented or advised, there is the likelihood of unfavourable outcomes for the government in agreements on tariff, taxes and duties. Lack of competition can also result in overstated capital costs[21] that can depress operating profitability, hence taxes and dividends.

***A lack of transparency admits the possibility of complicity between the parties.*** Transparency ensures an auditable process, without which inequitable agreements may be concluded in which rights, responsibilities, and risks are unbalanced. Transparency encourages participation of serious and reputable sponsors who will, in turn, attract technical assistance support from multilateral and bilateral agencies.

***A high degree of uncertainty is involved.*** Uncertainty relates not only to the prospects for success but also to the cost and time involved in achieving it. From the sponsor's perspective this complicates financing decisions and deters all but the most tenacious (and those with nothing to lose).

Against this background, a competitive bidding process for the wind energy project is strongly recommended.

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[21] Sponsors may seek to make money from the engineering, procurement and construction contract(s), either by direct participation in such activities or by closed-door negotiations with contractors. Lack of competition and transparency provides the opportunity of fixing high prices to maximise construction profits for the sponsor at the expense of the profitability of project company.

### *9.2 Alternative Procurement Model*

TAU has indicated that it may not be comfortable with a BOT procurement model. And indeed it may be worthwhile to consider the downside of such a model. Firstly, it involves higher transaction cost. The legal documents such as concession and power purchase agreements are complex and require input from legal specialists. Secondly, the developer will want a compensation for his assuming the major project risks in form a premium on the rate of return. Thirdly, a BOT model is not always easy to accommodate if a project has a component of grant funding. Perhaps more importantly, there is also a potential for disputes and conflicts over dispatch which may absorb precious human resources.

While we still believe that a BOOT model could be an attractive procurement model a viable alternative would be a EPC (engineer, procure, construct) contract. In such an arrangement TAU would specify the basic parameters of the project and procure the wind park as a turnkey facility in international competitive bidding. The contract would also include a period during which the EPC contractor operates and manages the facility while TAU staff is being trained to take over these tasks. The contract period should be at least five years and should include the provision of an insurance of the wind farm, in particular against hurricane damage.

### *9.3 Implementation tasks and institutional arrangements*

#### Lead Agency

It is recommended that TAU take the role of the lead agency for the project. It would under this role assume responsibility for resource assessments, landowner negotiations and would also co-ordinate further project preparation work.

#### Improving resource data

It is sensible for any nation to have a balanced range of energy technology, rather than relying on one technology and imported fuel. Although wind data need to be improved in the Cook Islands, it is clear that commercial wind energy is at present the most attractive renewable alternative for grid connected electricity generation. It is of paramount importance that the related resource risk is reduced by wind measurements on site. This could be done by the government or, if a BOOT/BOO transaction model is chosen, by short-listed developers.

#### Familiarization with the technology

Introducing commercial wind energy will increase energy diversity and improve the security of electricity supply. Energy diversity reduces the international political risks associated with fossil fuel reserves, vulnerability with respect to volatile oil prices, and the hazards associated with oil spills. Although the Cook Island’s wind regime will result in an intermittent generation of electricity, the resource still has value, particularly where its power production coincides with peak electricity demand or is complementary to the characteristics of the diesel plants supplying the TAU system. It is understood that the government and TAU feel uncertain about the new technology. It is therefore recommended that appropriate representatives of both the government and TAU conduct a study tour of the King Island wind energy project in Austarlia. This project is similar to the configuration proposed for the Cook Islands and has several years of operating experience. The Fiji Electrcity Authority FEA may also be willing to share its Butoni experience with their counterparts in other Pacific nations. Study tours could be part of the project preparation process and possibly supported by TA.

**International competitive bidding**

It is recommended that the government call for international competitive bidding for a BOO or BOOT-type project in a one-stage process. The basic design should be based on 2 MW. The Bidding document would include a draft power purchase agreement and a grid connection code that specifies TAU power quality and dispatch requirements. The fact that two proposals have already been tabled supports the view that a wind project in the Cook Islands could be procured in a competitive environment. A BOOT wind project has been successfully implemented in New Caledonia i.e. there is already experience for this type of transaction in the region.

If the government decides to proceed along these lines, it is recommended that the lease for one of the potential sites be secured for a period of at least 20 years in order to reduce land-related uncertainty for the bidders. An Expression of Interest from developers could be solicited immediately to test the market and to compile a shortlist of pre-qualified bidders. This could also be done for other procurement models as described in section 9.2.

In the one-stage bidding process that would follow short-listing, developers should be allowed to perform their own wind data measurements on site. As the sponsors must determine a binding project cost in parallel with discussions with contractors and suppliers, a generous tender period will be required; 12 months is recommended. It is not recommended that the Government takes an equity share in the project as this would undermine the risk allocation principles explained earlier.

The advantages of a competitive procurement for the government and TAU are:

- It maximizes the probability that wind energy would be successfully developed and that the project would achieve the Government's objectives.
- Competition on tariff would minimize electricity prices and avoid problems relating to manipulation of EPC prices.
- The tariffs tendered by sponsors are binding and if they are higher than expected, the Government/TAU has the option of deciding not to award the BOOT concession. (Under directly negotiated awards the Government may find itself locked into concessions before the final tariff is known.)
- The Government would have greater control over project design and standards of implementation by specifying these in the RFP.
- Risks would be equitably and effectively defined, minimized, managed and allocated.

### *9.4 TA for project preparation*

If the government decides to proceed with the project as recommended above, it should seek technical assistance. The project preparation and formulation activities would mainly include the preparation of the international tender (RFP) by an independent consultant. Additional activities would be a call for Expressions of Interest and perhaps study activities to familiarize decision makers with state of the art wind generation technology. One of the quickest (and independent) sources for such project preparation activities might be PIEPSAP or the World Bank operated PPIAF facility.