WIND RESOURCE ASSESSMENT,

FEASIBILITY STUDY AND PROJECT CONCEPT

DEVELOPMENT FOR AITUTAKI, COOK ISLANDS.

REPORT B:
- WIND RESOURCE ASSESSMENT REPORT.

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Part 1: AITUTAKI WIND ATLAS
COOK ISLANDS
ABSTRACT

For a number of years, the Government of the Cook Islands has shown clear interest in the development of renewable energy sources as an alternative to diesel powered generators commonly used to supply electricity to the population of its small islands.

This report, part of the approach, deals with wind mapping for Aitutaki - Cook Islands.

The study has been achieved to determine wind potential and location of windy sites.
PRESENTATION OF THE STUDY

1 Context and goal of the study

1.1 Presentation of Cook Islands and the Aitutaki Islands

GEOGRAPHY

The Cook Islands are located in the South Pacific Ocean between Samoa and Tonga on the West and French Polynesia on the East. The group is made up of fifteen islands scattered over 2 million square kilometres of ocean, an area as large as Western Europe.

Aitutaki Cook Islands is a triangular shaped ‘almost’ atoll: a central volcanic island surrounded by a barrier reef. The atoll rises up 4000 meters from the floor of the Pacific Ocean. The Main Island is Aitutaki, there are other uninhabited islands along the edge of the lagoon: 3 volcanic and 12 coral islets (motus). The lagoon is so large that the largest island in the Cook Islands can fit inside (12km*15km). The highest point of Aitutaki is Mt Maungapu, 124m.

CLIMATOLOGY

Cook Islands enjoy a mild maritime climate with a dry season (May to October) and a pronounced wet season (November to April) with tropical showers and higher humidity (two thirds of the annual rain falls).
temperatures range between 20° and 25°C.

The Cook Islands are in the southeast trade wind belt: the prevailing wind is from the southeast with occasional shifts to the north. Typhoons could occur during the wet season.

**WATER RESOURCES**

Lack of water is an important concern for Cook Islands: no water reservoir exists. The water source is from stream, roof catchment system, bore holes or water tanks.

**HISTORY AND POLITICS FACTS**

The first settlers probably came during the Great Polynesian Migration in 800 AD. Spanish sighted Pukapuka and Rakahanga in the late 16th and early 17th cent. Captain James Cook discovered Manuas atoll, Palmersont, Takutea, Mangaia and Atiu 160 years later.

According to the legend, Aitutaki was settled by a polynesian chieftain Ru in 900 AD. He named it: Utatak Erua O Ru Ki Te Moana. The 1st recorded discovery by Europeans was Captain Bligh in 1789. Shortly afterwards the mutiny occurred: Bligh returned later in 1792. He said to have introduced the paw paw fruit to Aitutaki which is now an important export product from the Cook Islands. The first missionary to the Cooks was John Williams. He landed on Aitutaki before any of the other islands.

Cook Islands were proclaimed a British protectorate at the end of 19th century and annexed the Islands in 1901. The country became self-governing in free association with New Zealand on 4 August 1965 and is free to unilaterally declare their complete independence.

Cook islanders have a New Zealand citizenship: they are able to live and work in New Zealand. An economic crisis in the mid-1990s led to outmigration and a significant drop in the islands population.

**POPULATION**

The current population is estimated at 20 000 people and half of the Cook Islanders live on the main Island Rarotonga. The people are mostly Polynesian (90%) and the minorities are principally Europeans or Chinese. The local language is Cook Islanders Maori but everyone speaks English. Aitutaki has a population of about 2000.

**ECONOMIC ACTIVITIES**

In Cook Islands Tourism is the major income earner and Aitutaki is the second most visited island. The second most important sector is the production of pearls. Exportations are also based on agriculture, fishing, pearls production and clothes manufacturing.

Agriculture produces copra, canned citrus fruit, papaya, coffee, pineapples, tomatoes, pawpaws, bananas, yams and taro. Manufacturing activities are based above all on fruit processing but also on clothing and handicrafts. Mining and fishing industries are being expanded.

**ELECTRICITY**

Electricity production system of Cook Islands completely relies on imported fossil fuels. Solar energy contributes to a very small proportion in energy generation.

The electricity consumption of the Cook Islands is 25.51 million of kWh (2001) or 1214.29 kWh per person (2001). Today thanks to government commitment 98% of the homes on Cook Islands have electricity.

**WIND ENERGY: A PART TO PLAY**

Wind is clean, renewable, and increasingly economical. This is an incredible opportunity to create a cleaner environmental future. Cook Islands benefits good wind conditions and enormous opportunities in wind power: this potential is worth to being valorized.

Wind could not solve all energy difficulties but it could contribute to play a role in energy power supply. The decentralized solutions have advantages:
Wind energy could be valorized thanks to wind power plan linked to islands existing grids or with a village wind power network for rural electrification. It is a reliable solution for rural electrification and also a good way to reinforce the electric grid.

Moreover wind energy could help to reduce the dependency of Cook Islands on imported petroleum products and to reduce the country’s energy costs.

1.2 Goal of the study
Energy division of Government of the Cook Islands have expressed interest in determining the wind regime of Aitutaki Islands for wind power production.

The aim of the study is to realize the wind mapping for Aitutaki Islands.

2 General methodology of wind mapping

The wind potential is studied according to a 3 steps methodology.

2.1 General analysis of the wind potential
The wind cartography for Aitutaki Islands has been realized thanks to meteorological and geographical data.

First, global meteorological input data were defined above the sea. Secondly, the terrain model and the vegetation data are digitalized and formatted. Finally, wind mapping is calculated by exploiting the representative meteorological input data, the land cover and numerical terrain model.

A global meteorological input data have been used to calculate wind reference potential. This wind reference potential has been transposed to the whole zone of study taking in account the vegetation and the elevation. Then the numerical simulation of wind mapping is launched (with wind expert software WAsP®).

2.2 Location of windy sites
Thanks to the wind map, the potential windy sites are pointed up. The windy sites should have a wind speed higher than 7m/s at a height of 30m above ground and should check the feasibility constraints of wind turbine project.

The best wind sites are deepened is the conclusion of this report.

3 GLOBAL WIND SAT Approach

3.1 Presentation of GLOBAL WIND SAT
The study of wind potential Aitutaki Islands uses an innovative method based on its characterization and quantification: The Global Wind Sat Approach.

The Global Wind Sat approach implements global wind data (from Winergy wind archive), numerical terrain model (which describes relief) and a rugosity model (which describes vegetation territories).

In this approach, cartographic calculation for wind mapping has been realized with wind expert software WAsP®.

This method is described and compared to the standard approach in order to define the wind potential.
Comparison between the standard methods and the innovative one

**Standard Method**: The standard principle of the wind calculation software is described in the diagram below.

- Some reliable and representative numerical wind data at one or several points (1)
- A precise Numerical terrain model for the concerned zone
- A precise description of the environment of the meteorological reference station (2)

Ground meteorological stations are often badly located; the neighboring environment (vegetation and buildings) disturbs wind measures. In addition, the relief around the meteorological station has influence on measure and therefore it should be accurately described.

The first and the second calculation stages have to be based on precise meteorological data. Indeed, meteorological data conditions take an important part in calculations and unfortunately there are many uncertainties about data from ground meteorological station.

Therefore it is necessary to have reliable, precise and non perturbed data which describes the local wind regime. Global wind data which are calculated above the ocean check all these criteria and thus the difficulties of stages 1 and 2 disappear.

**An innovative method**: The Global Wind Sat Approach: use of expert software WAsP® from global meteorological data and numerical terrain model.
Global Wind data

In order to exploit global wind data, within the context of wind site prospection, Winergy have set up a database at a 10m height.

Wind data from this archive have several origins:

- Satellite wind measures realized within the context of « Defense Meteorological Satellite Program » of the NASA. Satellites are equipped with Special Sensor Microwave Imager (SSM/I). Wind data are recorded at 10m height above the seas and the oceans of the world.
- Re-Analysis data from the European Center of Meteorological Predictions at Middle Course.
- Raw data measured in the national meteorology centers.

A numerical model (a method of 2D variational analysis) combines data from the several observation sources. This method enables to generate vectorial field at a 10m height above the surface. A complex numerical model of atmospheric flows is also involved. The reliability of these data is linked for one hand to its diverse origin (satellite sensors, surface measure) and for the other hand to the overall coherence obtained with the global atmospheric circulation. It enables to correct possible error or measure imprecision. This work has been realized by experts and scientists within the context of research strategic programs (defense, meteorological prevision). That is an additional guarantee of its performance.

Files of Winergy Wind Archive contain the component u and v of the wind speed at 10m height above the sea.

These values have been calculated every 6 hours UTC during a 13 years period (from 1998 to 2001). That gives precise long course estimation from various and regular measures.

Measures have been geographically referenced from a mesh: the grid is made up with cells defined by:

- A latitude range [-90° ;+90°] with a 1° step
- A longitude range [-180° ;+180°] with a 1° step

This meteorological grid is significant and reliable for studying wind potential above the ground.

The major interest of this prospective approach consists in exploiting global wind data which are recorded above the ocean. Thus we have at our disposal wind data for all points of the globe which are not disrupted by the surrounding relief. So these points are representatives of wide zones (100km radius). The following map is based on an historic of 12 years measure period (1998-2000) and resumes the average wind intensity and direction at 10m height above the ground.
Calculation Methodology

The calculation methodology follows a 4 stages reasoning:

- 1st stage: meteorological and topographical input data were treated and integrated: with a peculiar treatment for vegetation (cf. 4th paragraph)
- 2nd stage: calculation with WAsP®: mode calculation are set up. Simulations are launched. (Beforehand a calculation of wind reference potential has been realized).
- 3rd stage: the presentation of wind maps is finalized: Layout of the iso-speed plots given by WAsP® simulation.
- 4th stage: The wind geographical information system (GIS) is developed. A multi-criteria approach is suggested in order to set up a directive plan for wind power in Aitutaki Islands.
1.1 Terrain Informations

- Identification of the windy zones
  - Wind speed >7m/s
- Best sites selection
- Development of a wind directive plan

- Wind Simulation software WAsP®
  - (General calculation)
- Regional data basis of the wind potential
- Simulation: calculation of wind potential cartographies at 30m height
- Layout with Arcview®
  - Wind potential cartography
  - Development of the wind GIS
- Wind Atlas
- Identification of the windy zones
  - Wind speed >7m/s
- Prospects of the study

- Global meteorological wind data
  - (Winergy wind archive)
- Numerical terrain model and vegetation model
  - (paper map)
- Terrain Informations (paper map)
Interest and performance of the method

This innovative method distinguishes itself from the standard approach for determination of wind potential.

Interest:
- No research of land meteorological data.
- High quality of series of data wind (long and unbroken).
- Preliminary characterization of the wind regime without sites instrumentation.

Performances:
- Acceleration of wind study stage.
- Feasibility of study about area with rare or unworkable wind data.
- Precise evaluation of the wind potential on a zone at global scale.
- Identification and selection of wind farm sites.
- Tool for energy choices and country planning policy.

3.2 A validated method

This prospective method for wind potential determination has been validated by WINERGY and VERGNET over the New Caledonian territory.

VERGNET has been in New Caledonia for many years. Various measure campaigns are under way and some wind power plants came into being. Thus, it has been possible to compare the innovative approach with reliable measure campaigns.

This validation stage has allowed checking the quality of global wind data. It has demonstrated the interest and the pertinence of using that type of meteorological data for the wind potential determination.

Besides, Global Wind Sat approach was implemented to realize:
- Wind atlas of the Large coast of Senegal (initiated by the Energy and Hydraulics Ministry, the Senegalese Agency for rural Electrification and the Electricity firm SENELEC).
- Wind atlas of a coastal zone of Morocco.
- Wind atlas of the East of Madagascar (initiated by the Environment and Energy management agency – ADEME-DAI with the support of the Malagasy Energy and Mining Ministry).
- Wind map of Mangaia Island - Cook Islands (funded by the Secretariat of the Pacific Community (SPC)).
- Wind map of New Caledonia Main Island (EEC and Caledonian government).
- Wind atlas of Vanua Levu and Ovalau Islands (Republic of the Fiji Island - Department of Energy and Fiji Electricity Authority).
4 Data and simulation hypothesis

This paragraph describes the calculation hypothesis and the data which are integrated in the wind expert software WASP®.

4.1 Meteorological data: The wind

The meteorological data of this study come from the Winergy wind archive: it is a matter of global wind data from several origins as explained in the previous paragraphs.

For one meteorological input point of the Winergy wind archive, one statistic file is available. This file contains wind speed and wind direction every 6 hours over a 13 years period.

Wind data treatment consist in calculating from this annual chronics over 13 years: contingency tables, wind repartition tables per wind speed class (1m/s) and directional sectors (20°). It is the statistical treatment of wind information.

First, before calculation phase, meteorological input data have been analyzed in order to have a general approach of the climatology of the islands. Annual variation, seasonal variation and hourly variation are displayed in appendix (additional information about wind). Four meteorological points have been extracted and studied. The results of this process (contingency tables, wind rose and distribution) are available in appendix 1 named “additional information about wind”.

One point has been used to calculate the wind mapping. It is the most representative and the nearest point which has been used to characterize Aitutaki Islands: 19°W, 159°S.

4.2 Numerical Terrain Model

Relief description is fundamental to calculate wind circulation on a zone: the relief has a great influence on wind flows in low atmosphere layer. Consequently, specific sites effect speed up or slow down wind. That is why topographic are required for wind mapping calculation.

The elevation contours have been digitalized and formatted from a paper map of Aitutaki Islands 1:25 000 to obtain a numerical terrain model compatible with the expert simulation software WASP® (cf.appendice 2).

The map precision was one elevation contour every 10m height. The relief of Aitutaki varies from 0 to 124 m.

4.3 Roughness description

The wind flow is disturbed by land uses. The simulation software take into account this influence through a roughness description.

Vegetation data was also numerised with the same method as the numerical terrain model.

Each land use class has been defined and each class corresponds to a roughness value:
- Ocean or expanse of water
- Forest
- Village
- Plantation . . .

Vegetation of Aitutaki islands is composed of forest, trees and plantation.

4.4 Transposition of the wind reference potential to a specific zone

The definition of a regional wind potential is realized from global meteorological data statistic files (extracted from Winery wind Archive). Beforehand, these files have been converted to the simulation software standard. The wind referent regime is then transposed to the specific zone with relief, roughness conditions.

WASP® calculates the wind potential at a specified height by spitting up the map according to a grid.
on each point of the mesh, wind characteristics are calculated with a 2 dimensions flow analysis model. Then it is possible to link points with the same value, to plot iso-speed curves and thus to realize precise maps of the wind potential of the zone.

4.5 Calculation steps

The wind was calculated at 30m height.

Two calculation zones have been defined. First wind speed was calculated all over the Aitutaki Islands group with a 75m calculation step (each calculation points are 75m far from one to each other). Secondly, a more precised calculation has been realized for the inhabited Aitutaki Island: 35m calculation step.
The wind cartography of Aitutaki islands has been calculated at 30m height.

Colour scale has been chosen in order to differentiate low or moderate wind potential (green) from high ones which are favorable to wind turbines implantation (orange and red).
Figure 2: Wind Potential at 30m above the ground – Aitutaki Islands Group (Calculation step: 75m)
WIND MAPPING 30m above the ground - AITUTAKI ISLANDS

Figure 3 Wind Potential at 30m Above the Ground – Aitutaki Island (Calculation Step: 35m)
CONCLUSION

1 Synthesis of the study: favorable site for wind yield

The exercise of wind mapping has allowed quantifying the available wind potential.

The wind mapping confirms that trade winds come from southeastern: wind over the eastern coast is reinforced whereas wind speed over the western coast is slow down.

The trade wind seems to be more important on the northern hills of the Island.

Aitutaki Islands is composed of good sites with average wind speed higher than 7m/s (average value over 1 year at 30m height).

Best sites are encircled on the following maps. Wind measurements should be realized in that zone.
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WIND MAPPING 30m above the ground - AITUTAKI ISLANDS

Figure 4 Location of good wind potential sites – Aitutaki Island
1 Additional Information about wind

1.1 Location of the several global meteorological points

Four global wind sat point have been analyzed in order to have a general approach of the climatology of the islands. Annual variation, seasonal variation and hourly variation are displayed in appendix (additional information about wind).

One point has been used to calculate the wind mapping. It is the most representative and the nearest point which has been used to characterize Aitutaki Islands: 19°W, 159°S.

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>station 1</td>
<td>XUTM: 605254, X°: -19, YUTM: 7898874, Y°: -158</td>
</tr>
<tr>
<td>station 2</td>
<td>XUTM: 500000, X°: -19, YUTM: 7899173, Y°: -159</td>
</tr>
<tr>
<td>station 3</td>
<td>XUTM: 605867, X°: -18, YUTM: 8009529, Y°: -158</td>
</tr>
<tr>
<td>station 4</td>
<td>XUTM: 500000, X°: -18, YUTM: 8009815, Y°: -159</td>
</tr>
</tbody>
</table>

**Station used to calculate the wind mapping**

1.2 Wind Distribution (at 10m height)

<table>
<thead>
<tr>
<th></th>
<th>V moy</th>
<th>A</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>station 1</td>
<td>6.2</td>
<td>7.0</td>
<td>2.31</td>
</tr>
<tr>
<td>station 2</td>
<td>6.3</td>
<td>7.1</td>
<td>2.34</td>
</tr>
<tr>
<td>station 3</td>
<td>6.3</td>
<td>7.1</td>
<td>2.36</td>
</tr>
<tr>
<td>station 4</td>
<td>6.4</td>
<td>7.2</td>
<td>2.40</td>
</tr>
</tbody>
</table>
1.3 Wind Roses (at 10m height)

Wind direction above the ocean around Aitutaki is 100-120° thus Aitutaki is as expected in the southeast trade wind belt.

1.4 Monthly variation
The average wind speed varies with the month of the year. We could notice that during the rainy season the wind speed is less important whereas during the dried season the wind speed keeps increasing.

1.5 Evolution per year

![Graph of wind speed evolution per year](image)

Wind speed is constant from 1987 to 1995. From 1996 to 1998, the average wind speed increases: it is probably due the the climatic phenomenon 'El Niño'.

2 Aitutaki paper map
Part 2: 8.5 MONITORING MONTHS REPORT
Introduction

In a first part, a wind atlas has been calculated for the whole island of Aitutaki. In a second part, a 30m height monitoring mast has been tilled up in order to precise the wind potential. This report summarizes the result of the wind analysis at the mast.
Results

1 Location

FIGURE 5: LOCATION OF THE WIND MONITORING MAST
A tall tower was erected approximately at 100m South-East of the Maungapu peak. The elevation of the mast is approximately 80m a.s.l.

The approximated coordinates of the mast are:
- \( X = 417.574 \text{m}, \)
- \( Y = 7.916.696 \text{m}. \)

The site is named “Maungapu site”.

## Installation

### 2.1 Installed equipment

- **Type**: Tubular tower
- **Brand**: NRG systems
- **Hauteur**: 30m
- **Instrumentation**:
  - 1 anemometer at 30m,
  - 1 anemometer at 20m,
  - 1 wind vane at 30m.
- **Acquisition**: logger NRG 9200

### 2.2 Operations:

- Erection and set up: the tower erection was finished on the 14th July 2005 but data record started on the 17th August 2005.
- Frequency of the data recovery: every month

### 2.3 Measured Parameters

#### Wind speed

Measured at 30m and 20m.

Wind speed is measured at a 2 seconds interval and averaged every 10 minutes.

#### Wind Turbulence

Measured at 30m and 20m.

This parameter quantifies rapid variation (<10min) in the wind speed.

Turbulence is expressed by the typical variation in wind speed over 10 minutes.

#### Wind direction

Measured at 30m

Wind direction is measured at a 2 seconds interval and averaged every 10 minutes.
3 Quality of the measurement

3.1 Completion rates

Completion rate = number of measurements achieved / number of possible measurements

<table>
<thead>
<tr>
<th>parameter</th>
<th>period of recording</th>
<th>completion rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed at 30m A1</td>
<td>from 17/08/05 10:00 to 01/05/06 12:00</td>
<td>92%</td>
</tr>
<tr>
<td>speed at 20m A12</td>
<td>from 17/08/05 10:00 to 01/05/06 12:00</td>
<td>92%</td>
</tr>
<tr>
<td>direction at 30m G1</td>
<td>from 17/08/05 10:00 to 01/05/06 12:00</td>
<td>92%</td>
</tr>
</tbody>
</table>

Some data have been lost from 30/11/05 au 19/12/05. The completion rate is good; therefore all the records are representative of the measurement period.

3.2 Chronicle of the measurements

The chronicle shows that during all measurement period, wind speed record at 30m and 20m were kept up faithful and as expected the wind speed at 30m is always higher than the wind speed at 20m. The wind vane seems also to work correctly during all the measurement period.

4 Wind speed
### 4.1 Average wind speed

<table>
<thead>
<tr>
<th></th>
<th>a-05</th>
<th>s-05</th>
<th>o-05</th>
<th>n-05</th>
<th>d-05</th>
<th>j-06</th>
<th>f-06</th>
<th>m-06</th>
<th>a-06</th>
<th>average speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed at 30m A1 (m/s)</td>
<td>7.3</td>
<td>8.1</td>
<td>5.9</td>
<td>5.4</td>
<td>5.2</td>
<td>6.0</td>
<td>4.8</td>
<td>5.1</td>
<td>7.4</td>
<td>6.1</td>
</tr>
<tr>
<td>speed at 20m A2 (m/s)</td>
<td>8.6</td>
<td>7.4</td>
<td>5.5</td>
<td>5.0</td>
<td>5.0</td>
<td>5.6</td>
<td>4.5</td>
<td>4.8</td>
<td>6.7</td>
<td>5.7</td>
</tr>
</tbody>
</table>

(* note that august month is since 17/08/05)

We can note that the wind speed varies with seasons. We have not a complete year measurement but as expected the dry season from May to October appears to be windier than the wet season from November to April. The months we did not have (May, June, July and half of August month until 16/08) would have been in the windy season and increase the mean wind speed.

Wind speed hardly varies along the day.

### 4.2 Wind speed distribution and Weibull model

The wind speed varies from the time. The experience shows that the wind speed distribution is well modeled by the Weibull curve. The graphic bellow shows the Weibull distribution and determines the shape factor k and scale factor A of the model.

The wind distribution at the mast is well modeled by the Weibull model.

**Maungapu Site - 30m mast - Anemometer A1 at 30m**

Wind speed distribution

at 30m above ground level - from 17/08/05 10:00 to 01/05/06 12:50

![Wind speed distribution graph](image)

**FIGURE 7: WEIBULL DISTRIBUTION AT 30 M**

**Average wind speed = 6.1 m/s**

A = 6.9 m/s

k = 2.4
5 Direction

The wind conditions of a site are depending on the direction of the wind. Topographical effects and regional climate determine the main direction of the flow.

A wind rose is calculated on the site: it defines the frequency of the wind for each direction and the repartition of the energy of the wind for each direction.

![Wind Rose Diagram](image)

**Figure 8: Wind Rose at 30m**

As expected we find the direction characteristic of the trade winds in the South Pacific: from East to South.

<table>
<thead>
<tr>
<th>G1</th>
</tr>
</thead>
<tbody>
<tr>
<td>main energy sector °</td>
</tr>
<tr>
<td>energy in this sector %</td>
</tr>
<tr>
<td>main direction °</td>
</tr>
</tbody>
</table>

6 Turbulence
Maungapu Site - 30m mast - Anemometers A1 at 30m and A2 at 20m
Turbulence - comparison to IEC norm
30m et 20m above ground level - from 17/08/05 10:00 to 01/05/06 12:50

Turbulence means rapid variations (<10min) of the wind speed. An irregular wind could have bad effects on wind turbines: it could affect the lifespan of the turbines and the production.

Turbulence is expressed in m/s: this is the typical range (σ) of the wind speed recorded every 2 seconds over 10min.

Turbulence intensity is defined as: TI = σ/average wind speed (%)

Turbulence study consists in comparing site turbulence to the theoretical admissible turbulence fixed by the international norm IEC 61 400-1:

- The lower limit is the threshold beyond which turbulence leads to disturbance in production
- The upper limit is the threshold beyond which turbulence provokes either premature wear or degradation to the machine

The turbulence level on the site stays under the limit. Turbulence is not a problem for wind turbine installation. The turbulence at 30m is lower than 20m; we can suppose that it would be lower at 55m.
wind speed estimation at 55m

1 Vertical gradient

This parameter defines the wind speed variation with elevation. The wind speed increases more or less rapidly with elevation in relation with the land cover of the site.

\[ \alpha = \frac{\ln (V_{H1} / V_{H2})}{\ln (H1 / H2)}, \text{avec } H1 > H2 \]

\[ H1 = 30m \text{ and } H2 = 20m \]

With the vertical gradient we can estimate the wind speed at higher elevation.

\[ V_{H3} = V_{H1} \times (H3 / H1)^\alpha \]

\[ \alpha = 0.19 \]

This vertical gradient is high. No photo is available but in the map we could read that there is no high vegetation on the site. Therefore, this vertical gradient could be not representative of the wind profile between 30m and 55m. **To be conservative and not to overestimate the potential a vertical gradient of 0.15 will be used for the following calculations.**

2 Calculation of the wind speed at 55m

We can estimate the wind speed at 55m with the vertical gradient \( \alpha \):

Wind speed \( 2 = \text{wind speed}_1 \times (\text{height}_2 / \text{height}_1)^\alpha \)

With: \( \alpha = 0.15 \)

**Wind speed at 55m at the mast from 17/08/05 to 01/05/06 = 6.7 m/s**

(With \( \alpha = 0.2 \) we would have found 6.9 m/s)
3 Representativeness of the measurement period

Wind turbines are installed for a period of 10 or 20 years. Wind has a seasonal variation but it changes also from one year to another. Therefore, it is interesting to know the average wind speed at long term that is why it is used to correlate the wind data at a site and some meteorological data available at long term.

WINERGY had no meteorological data in Cook Islands.

Some meteorological wind speed data are available at the web site: [http://www.weatherunderground.com](http://www.weatherunderground.com):

- Meteorological station of Rarotonga Island: from August 98 to August 06
- Meteorological Station of Aitutaki Island: from June 04 to August 06

It is important to note that we do not know the quality of the data which could be downloading on the web site.

<table>
<thead>
<tr>
<th>Station Rarotonga</th>
<th>from 17/08/05 to 01/05/06</th>
<th>from 01/01/98 to 31/08/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion rate</td>
<td>100%</td>
<td>97%</td>
</tr>
<tr>
<td>Wind speed (m/s)</td>
<td>3.7</td>
<td>3.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station Aitutaki</th>
<th>from 17/08/05 to 01/05/06</th>
<th>from 01/06/04 to 31/08/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion rate</td>
<td>85%</td>
<td>85%</td>
</tr>
<tr>
<td>Wind speed (m/s)</td>
<td>9.5</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Rarotonga station tends to show that the measurement period is a little windier that the long term whereas the Aitutaki station shows that it is a little less windy. But it is important to notice that the completion rate of Aitutaki is not perfect and we have few measurement years.

In Rarotonga station, we can notice that there is a real yearly variation. In Rarotonga station, we could notice the 2 seasons (wet and dry) but the wind speed is practically the same.

It is not possible to conclude if the measurement period is or is not windier than a typical year. We could just note that the period seems not to be exceptionally windier or less windy than usual.
Conclusion

8.5 months of data have been collected and analyzed in this report at 30m mast. It allows knowing the wind potential of the Mangapu site in Aitutaki. During the period of the measurement campaign:
- A wind speed at 30m of 6.1 m/s,
- A Weibull shape factor of 2.4,
- An estimated wind speed at 55m of 6.7 m/s,

WARNING:
We have not one year measurements: it lacks May, June, July and half of the August month; these months seem to be in the dry season and therefore more windy than usual. That could increase the yearly average wind speed.

No meteorological data were available for this study. Some meteorological data were downloading on the web but the quality and accuracy of these data is unknown. It just helps to conclude that the measurement period seems not to be exceptionally more or less windy than usual.