# Tuvalu Renewable Energy Study

## Current Energy Use and Potential for Renewable Energies

March 2006.
Final Draft

An Alofa Tuvalu[1] Report
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Funded by

- The French Ministry for Foreign Affairs (Pacific Fund)
- ADEME – Agence de l'Environnement et de la Maîtrise de l'Energie

At the request of the Government of Tuvalu.

| Document control | |
|---|---|
| File path & name | Tuvalu_Renewable_Energy_study_final.doc |
| Authors | Sarah L. Hemstock<br>Pierre Radanne |
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| Field Assignment | July-September 2005, March 2006 |
| Analysis | October 2005-March 2006 |
| Distribution level | For open distribution |

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# EXECUTIVE SUMMARY

Tuvalu's environment is under pressure: sea-water rise contaminating the soil with salt, direct impact on waste and sewage systems from rising human density contributing to further damage. The 1987 UN Brundlandt report has definitely shown the existing link between environment/ecology and development /economy. Tomorrow's economy stems from today's environment. Investing in the quality of soil, avoiding water pollution, protecting natural resources especially energy sources as well as fighting against climate change will largely determine the success of Tuvalu's development for this new century.

The current study concerning renewable energy potential and implementation in Tuvalu is at the crossroad of 2 issues, each with major strategic implications: climate change threats and worldwide oil crises.

Given this context, what can renewable energy contribute to Tuvalu's benefit?

Analysis of Tuvalu's energy consumption reveals the following characteristics:

- Tuvalu's economy is almost totally dependant on oil. Only around 18% comes from local biomass resources, which is not accounted for in official statistics and is not the object of any active policy.
- Consumption for transportation: primarily sea transport and recently, road transport, account for over 50% of total current energy consumption.
- Prime importance of electricity production: courtesy of a Japanese aid program, an initiative to reinforce production with new diesel generators is slated to be implemented on Funafuti in 2006 continuing Tuvalu's dependence on imported oil.
- The 3rd highest energy consumption, thermal use (cooking, boiling water for drinking, sanitary hot water), is mainly provided by biomass.

It emerged from the study that the recent oil shock had particularly devastating effects: not only increase in cost of imported oil but also cost of all other imported products as well, including food, household equipment and building materials. These negative economic and social aspects are even more pronounced in the outer islands than on Funafuti.

It is also clear that any actions aimed at reducing imported oil dependency will help decrease greenhouse gas (GHG) emissions, reduce Tuvalu's impact on global warming and put Tuvalu on the road of a sustainable and exemplary development, giving the nation a stronger bargaining position in international negotiations.

The fieldtrip analysis also revealed Tuvalu's other development issues where renewable energies can bring active solutions:

- Waste management: because of lack of adequate equipment, household and municipal waste have long gone beyond the limits of the official landfill implemented in 2000 via an Australian Aid project, without a protective layer to prevent seepage of waste material into the surrounding land. Waste takes up more and more of Funafuti's scarce land and spoils soil and lagoon water. 70 to 80% of this waste is organic; producing energy and enriching the soil with compost could enhance its value.

- Lack of a collective solution for wastewaters creates further pollution and has many sanitary impacts, one of which is a reported increase in skin diseases.

The renewable energy study is aimed at proposing solutions to immediate issues as well as future ones. Proposals made in this report have been drawn with several deontological priorities:

- Choice of appropriate technologies whose feasibility has been demonstrated and well established in equivalent conditions: considering the country size and its isolation, it is clear that excessive difficulties could result in failure if an inappropriate and experimental technology were to be selected. For example, appropriate biomass technologies highlighted by this report include coconut oil for biodiesel production and digestion of organic waste for the production of biogas, both well established and well documented technologies.
- Reduce functioning and maintenance costs after initial investment. Initial investment could be largely supported by international cooperation (bilateral or multilateral) and ongoing function and maintenance run by a well trained and equipped Tuvalu-based Service Provider (similar to Tuvalu Electricity Corporation - TEC).
- Develop Tuvalu's autonomy and reduce its vulnerability to international oil price increases and, at the same time, develop local employment via production of energy sources, paying particular attention to the outer islands.
- Favour energy savings (via: efficiency, use of appropriate technology and fuel switching) to insure improved quality of life and environment at a lesser cost within the 2 key energy sectors: electricity consumption and transportation.

On this basis, the study's main recommendations are as follows:

✓ ***RENEWABLE ENERGIES DEVELOPMENT***

***Biomass resources enhanced value:***

The study clearly suggests that various types of biomass development can constitute the country's main energy resources for a long period of time. They offer further advantages: the optimization of the islands' indigenous resources and local employment and income generation. To implement biomass development, traditional resource usage will have to be improved and new ones developed.

- *To develop biomass use for cooking.*

Cooking from wood and coconut husks and shells still represents the majority of the country's energy consumption. It is essential to develop this by offering convenient use and higher efficiencies, rather than letting kerosene usage increase. Currently, biomass is almost double the domestic energy use of kerosene. Improved cooking stoves and energy carriers such as biogas will "modernise" the traditional use of biomass energy for cooking. In addition they will decrease the emission of GHG's and air pollution and improve household incomes as less will be spent on kerosene.

- *To locally produce and use biodiesel from copra for maritime transportation.*

Ocean transport has the heaviest impact on Tuvalu's economy as it insures vital overseas and inter - islands links. The engines of the inter-island boats are well suited to the use of coconut oil biodiesel and must take a leading role in the future by using locally produced copra biodiesel Using coconut oil biodiesel along with existing infrastructure and practices in this way may offer the most economically, culturally and environmentally sustainable solution to renewable energy development and re-vitalisation of the copra industry.

Tuvalu has been and continues to be a copra producer. Numerous experiences of using biodiesel for sturdy, low rpm marine-type engines have occurred throughout the world. For other types of organic oil, an experimentation step must be engaged, requiring both lab tests and on-site studies with the help of international partnerships. Future ethanol production from organic material could also be investigated.

***Produce energy by finding the value in waste:***

- *To produce biogas from organic and animal waste* and enhance its value by using it for household needs (cooking, boiling water for drinking) and decentralized electricity production.

Biogas production from organic matter methanisation in biogas digesters offers multiple advantages such as reduction of organic waste volume and environmental pollution and production of household energy which is appropriate for local needs. Biogas can also be used as a diesel substitute and so contribute to electricity production. In addition, the process produces a high quality compost to enrich garden soil, so promotion of family gardening to reduce food imports and improve general nutrition should go hand in hand with the introduction of digester technology. The use of these robust and economical technologies has been well established in China and India and is spreading in Europe.

***To Develop solar energy:***

- *To produce sanitary hot water from solar collectors.*

Individual or collective sanitary hot water production would make for real progress in terms of comfort and hygiene. It can be developed by importing existing equipment (the world's main producer is from Australia), making sure to choose the simplest and most salt-corrosion resistant equipment.

- *To use solar cookers.*

Besides the energy aspect, solar cookers can help insure the essential sanitary function of boiling rain water for drinking. This technology could also be used for drying copra quickly and effectively.

- *To produce electricity from PV cells.*

Photovoltaic energy, in use in Tuvalu for over 20 years, is a promising electricity production solution but where there is also significant room for technological and economical improvement.

Beyond the historical difficulties, due more to weak management and implementation than to technology, solar development has restarted and needs to be taken further in Tuvalu, starting with Niulakita where solar is the only and most appropriate energy resource.

For the other islands, the first step should consist of implementation where it is economically viable – such as installations for public lighting and security systems (as has been demonstrated in Kiribati). Progressively, solar energy can be integrated into on-grid installations.
Photovoltaic know-how should be developed in order to benefit Tuvalu in the longer term.

***To develop wind energy:***

Wind energy offers a good RE (Renewable Energy) option for island conditions: a mature and well established technology that needs little maintenance, a very advantageous cost compared to diesel generation. However one disadvantage is intermittent production. Funafuti's wind statistics were consolidated from the Meteorological Office data. It shows that winds have a weak average (5meters/sec when potential is considered favourable starting at 7m/s) and an irregular potential as well. However data was partial and the mast gathering data was only sited 10m above ground level.

Before the potential of wind generation can be assessed comprehensively, a full year of data must be gathered from a 30-40m high mast as this is the height of the windmill blades. This technology is very favourable at an economic level and would be a positive RE resource for Tuvalu. However, before implementation the resource potential needs to be confirmed for Funafuti and analyzed for each of the outer islands.

***Other renewable energy sources :***

Other renewable energy technologies are conceivable, such as ocean energy (currents, tides, waves) but these technologies are still at the experimental stage and no industrial or commercial-scale installations exist yet. These technologies are not considered in this report but may be worth considering for Tuvalu when they have been demonstrated in several comparable situations elsewhere and when costs have decreased.

### ✓ *ENERGY EFFICIENCY IMPROVEMENT*

Although energy savings did not constitute the study's main objective, it remains essential to bring the decision makers' attention to the fact that technologies and behaviours which improve energy efficiency are frequently the most cost-efficient strategies. Energy efficiency improvements represent a real strategic interest to a country where imported energy is structurally very costly. In addition, energy efficiency improvements have been identified by the IPCC (Intergovernmental Panel on Climate Change) as one of the key climate change mitigation strategies and by slight changes in behaviours and appliances, could save around 33% of current energy use..

***Buildings :***

The energy performance of buildings is greatly determined by initial design and quality of construction, for their lifespan i.e. often up to 100 years. Clearly, construction will be faced with fossil energy cost increases due to short supply and climate change. It is necessary to set a standard of energy performance within a construction code framework. In Tuvalu's situation, it should focus on protection from direct sun exposure (insulation) and resultant overheating: outside walls insulation, solar protecting caps or awnings (on the East, South and West sides, in particular for glass surfaces) and ventilation management. These techniques should be aimed at reducing use of air conditioners that simultaneously create soaring rise of electricity consumption and more and more consumption peaks on the grid. Such a thermal building code must be implemented progressively, starting with public buildings.

***Transport:***

Paying particular attention to sea and road transportation:

- Ocean transport plays a vital role for Tuvalu, a geographically scattered country. Oil price increases make research for improvement in ships energy efficiency essential. In addition, since a high proportion of costly imported diesel oil is used for sea transport, Tuvalu would do well to look to its own natural resources and substitute coconut oil biodiesel for imported mineral diesel oil. Fuel substitution on the two inter-island ships should be considered a high priority.
- In parallel, the quick and large increase in road vehicles these last few years on Funafuti, creates a coherence problem between the total number of cars, traffic issues and the actual road transport needs in such tiny islands. If we do not want to see further oil import imbalances as Tuvalu imports even more oil, it is necessary to set up power (vehicle engine size), speed and emissions limits for all non-specialized vehicles.

***<u>Household equipment :</u>***

A large proportion of Tuvalu's electricity consumption is a function of the energy efficiency of imported products. It is in the nation's economic interest to set up minimum performance levels for imported household and professional equipment: lighting, cooling, cooking, washing, television sets and other electronics equipment. Energy efficiency standards are normal practice throughout the EU and North America, so equipment can be sourced at competitive prices and should therefore not present an additional cost to the consumer.

✓ ***THE OUTPUT OF THE PRESENT STUDY POINTS OUT THE GOVERNMENT OF TUVALU'S (GoT's) INTEREST IN:***

- Deciding on a national energy plan with the central objective of reducing oil dependency and as a co-benefit, reducing GHG production and climate change impacts; this scheme will combine energy efficiency progress with renewable energy development: thermal solar, PV, bio diesel, biogas, traditional biomass and wind energy. A PIEPSAP (Pacific Islands Energy Policy and Strategic Action Plan) National Energy Policy Framework has been developed for Tuvalu which emphasises renewable energy technologies (RET's) for sustainable development. Once the GoT has accepted this framework, it must be put into practice. It is essential that future activities match policy objectives.
- Developing a voluntary policy for biomass use within a larger global framework covering renewable energy production, waste pollution reduction, soil enrichment with compost, economic and employment development on every island. An integrated approach to sustainable development must be emphasised.
- Arranging international cooperation to help allow these two policies to be implemented. Long term support covering financial, technical, training & institutional issues will be required to bring about these changes.

A first objective - to bring renewable energies contribution from 18% to 40% - is possible by developing biomass and thermal solar use in favourable economical conditions. This contribution could be progressively brought up to 2/3 of the energy supply within one generation, with more biodiesel, PV, and wind-power. Wind measurements will help define what proportion wind energy could represent to Tuvalu's renewable energy future and a coconut replanting program will insure future biodiesel production.

For all of these technologies and behaviours, know-how and awareness must be passed on to the Tuvaluan people, for Tuvalu to benefit most fully from renewable energy in the long run. Awareness raising and training in both operations and ongoing system maintenance are the keys to sustainable RET and waste management development.

The future of Tuvalu is clearly bound to the capacity of major industrialized countries to combat climate change. Nevertheless, it is essential to promote Tuvalu as an example of a successful development process with low level of GHG emissions. Doing so will not only measurably improve Tuvalu's economy, security and well-being at home, but by « taking care of its own house », it will also significantly strengthen Tuvalu' moral position and leadership in advocating its case regarding climate-change issues on the world stage.

**ABBREVIATIONS / GLOSSARY**

| | |
|---|---|
| ADB | Asian Development bank |
| AusAID | Australian Agency for International Development |
| BAO | Build and Operate |
| CME | Coconut Methyl Ester |
| CNO | Coconut oil |
| CO2 | Carbon Dioxide |
| FK | Funafuti Kaupule |
| GHG | Green House Gas |
| GoT | Government of Tuvalu |
| MSW | Management Solid Waste |
| NGO | Non Governmental Organization |
| PIGGAREP | Pacific Island Greenhouse Gas abatement Renewable Energy Program |
| PICCAP | Pacific Islands Climate Change Assistance Programme; |
| PIEPSAP | Pacific Islands Energy Policies and Strategic Action Planning; |
| PIREP | Pacific Islands Renewable Energy Project |
| PV | Photovoltaic |
| RE | Renewable Energy |
| RET | Renewable Energy Technology |
| SiB | Small is Beautiful |
| SOPAC | South Pacific Applied Geoscience Commission |
| SPREP | South Pacific Regional Environment Programme |
| SVO | Straight Vegetable Oil |
| TANGO | Tuvalu Association of Non Government Organisations |
| TCS | Tuvalu Cooperative Society |
| TCTC | Tuvalu Copra Trading Cooperative |
| TMP | Tuvalu Model Piggery |
| TSECS | Tuvalu Solar Electricity Cooperative Society |
| TEC | Tuvalu Electricity Corporation |
| TMTI | Tuvalu Maritime Training Institute |
| TWMP | Tuvalu Waste Management Project |
| UNDP | United nation Development Program |
| VME | Vegetable Methyl Ester |

Measures and currencies

| | |
|---|---|
| $ | US dollar |
| A$ | Australian Dollar |
| €. | Euro |
| £ | UK Pound |
| GJ | Giga Joule |
| Ha | Hectare |
| Ktoe | Thousand ton of oil equivalent |
| kW | KiloWatt |
| m.s- | Meter per second |
| MWh | Mega Watt Hour |
| $s.h^{-1}$ | Seconds per hour |
| toe | Tonnes of oil equivalent |
| Wc | Watt capacity |
| Wp | Watt Power |
| bl | barrel (200 litres) |

**REPORT CONTENTS**

# I INTRODUCTION

## I.1 BACKGROUND

This study comprises Phase I of the integrated development project: *"Small is Beautiful"*. The purpose is to quantify current primary energy use (from renewable & non-renewable sources) and to identify potential renewable energy resources as well as estimate their implementation economic viability.

In addition, this study makes a series of practical recommendations which, if implemented, would provide Tuvalu with practical means of fulfilling GoT's energy policy commitments to renewable and PIGGAREP's (Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project) aims:

1. To reduce the growth rate of greenhouse gas emissions (GHG) emissions from fossil fuel use through the widespread and cost effective use of their renewable energy (RE) resources;
2. To remove major barriers to the widespread use of RE technologies (RETs);
3. To increase the number of successful commercial RE applications;
4. To expand the market for RET applications for power generation and productive uses and to enhance institutional capacity to design, implement and monitor RE projects;
5. To improve availability and accessibility of financing to existing and new RE projects;
6. To strengthen legal and regulatory structures in the energy and environmental sectors;
7. To increase awareness and knowledge on RE and RETs among key stakeholders.

The Government & people of Tuvalu are already very supportive of the "Small is Beautiful" project and study and, in September 2005, Alofa Tuvalu obtained an agreement from the Minister of Energy and Transport to pursue the study in coordination with concerned directions.

## I.2 OBJECTIVES AND SCOPE OF STUDY

The objective of this study is to assist the Government to achieve the aims listed above by determining:

- Current sectoral primary energy use;
- Renewable natural resources available for energy use;
- Appropriate technical and administrative interventions;
- Capacity estimates of appropriate RETs;
- Cost estimates of appropriate RETs.

The work involved:

- Reviewing current energy provision and use in Tuvalu (in-country survey & research: July-September 2005);
- Providing basic estimations of renewable natural resources available in Tuvalu (in-country survey and research: July-September 2005);
- Meeting with local community groups and representatives to determine requirements and acceptability of various RETs (in-country research: July-September 2005);
- Identifying appropriate renewable energy resources;
- Liaising with GoT representatives;
- Estimating the likely capacity, operating characteristics, costs and other relevant factors of potential renewable energy capacity additions, identifying the partnerships needed for implementation;
- Identifying the partnerships needed for implementation.

## I-3 EXPERIENCE OF AUTHORS (RESEARCH/CORPORATE/ORGANISATIONAL)

**Dr. Sarah Hemstock**, **S H Solutions,** holds a PhD in Biomass Energy Systems and is an adviser to the "Small Is Beautiful" project. Currently she is Program Manager of the Cusichaca Trust, Director of Themba Trust, and was a Lecturer on "Energy and the Natural Environment" at King's College, London. As a consultant for SOPAC and Imperial College, London, she has visited several SIDS and published on bioenergy in the Pacific. Over 16 years she has worked on biodiesel, bioethanol, CHP, gasification and biogas projects in Africa, Europe, India, South America and the US.

**Pierre Radanne**, a well-known French environmental scientist and planner for over 30 years, specialized in renewable energy, is managing the consulting firm **Futur Facteur 4**. One of the French negotiators at the Kyoto Conference, he was at the origin of the first Energy and Waste Management National Agency in France in the late 70's and became president of the French Agency for Environment and Energy Management (ADEME) between 1998 and 2002. His Alofa Tuvalu project participation deals primarily with solar and wind energy issues in Tuvalu.

**Gilliane Le Gallic**, **Alofa Tuvalu** association's President, has been managing communication and production companies for over 25 years. She produced and directed many news and documentary series and specials such as "Trouble in Paradise" with co-director Christopher Horner. An environmentalist, she created "Earth Day" 1990 in French-speaking countries, initiating the participation of over 10 million French citizens. Author and coordinator of the "Small is Beautiful" project.

# II THE NATION OF TUVALU: A BRIEF OVERVIEW

Located 1100 km from Fiji, Tuvalu is composed of 9 islands, disseminated on nearly 1 million km2 of territorial waters. The distance between each island is about 100 km. These geographical conditions have great consequences for the economy. The total population is around 10,000 people: over 4,000 on the capital, Funafuti, 1,500 on Vaitupu, between 400 and 700 on 6 of the other outer islands (Nanumea, Nanumaga, Nukufetau, Niutao, Nui, Nukelaelae), and less than 50 on Niulakita. With a total land surface of only 26 $km^2$ the population density is high.

If the country's main resource comes from the ocean, agriculture is far from being self-sufficient and consists primarily of coconut and banana trees. Pig keeping is also very much a part of Tuvaluan culture and a food source for many households.

The remoteness of these islands has three major effects:

- A high level of cost for imported goods due to shipping,
- A lack of exports;
- A limited potential for tourism development.

In 2003, Tuvaluan exports represented 147 000 A$ compared with 24 Million A$ imports[2]: 160 times greater. This situation is unsustainable and presents a high level of risk of chronic financial shortage.

The imports consists essentially of :

- Food and beverages which account for around 25%. During recent years, eating habits changed in the direction of a greater part of food import rather than local production.
- In 2003, before the drastic increase in cars on the main island and before the construction of the government building, oil represented around 15% of the country's imports,
- The remaining imports comprised construction materials, equipment (domestic appliances, electronics and vehicles…)[3].

Because of this economic background, the government has made huge efforts to find new resources. Additional sources of revenue for the country are:

- Duties for boats of other nations fishing in the Tuvaluan territorial area (Exclusive Economic Zone – EEZ);
- Employment of seafarers, trained at the Tuvalu Maritime Training Institute, in overseas shipping companies;
- Licensing the ".tv" internet domain name;
- Interest fron the National Trust

[2] Quarterly Statistical Report, December 2004-August 2005-United Nations Common Country Assessment

[3] The most recent data available was from 2003.

To complete the national budget, the government of Tuvalu has no choice but to raise funds from international public aid (bilateral and multilateral). International donors have provided for Tuvalu's major country investments such as the hotel, the hospital, the government building and in 2006, the new diesel electricity generation plant. Income from aid is highly unpredictable and any disruption could cause great damage to crucial imports which are vital for daily life such as food or oil supply. Tuvalu is currently importing the vast majority of its energy in the form of fossil fuel which is a major drain on foreign exchange resources. In addition, the country is highly vulnerable to oil supply disruptions and because of the transport distances involved, it is liable to pay a considerable premium over world market rates for its future petroleum resources. These facts alone should be enough to persuade Tuvalu's decision makers of the value and potential of Tuvalu's indigenous energy resources.

# III REVIEW OF TUVALU'S ENERGY SECTOR

## III.1 THE WORLD ENERGY CONTEXT

Tuvalu's situation is now more worrisome than ever as the world is facing a new oil crisis. The following graph shows crude oil average price for the last 35 years expressed in US$ (all prices relate to the value of US$ in 2003). After the first oil crisis of 1973, the price rose to the average level of 48$ per barrel. After the second one in 1979, the average price stabilized at 62$ for 6 years until 1986, after a short peak beyond 80$. For the 1986 to 2000 period, the price stabilized around 24$. The December 1985 counter oil crisis was caused by the stabilization of oil consumption in the OCDE countries (oil substitution to coal, gas and nuclear and energy savings). The discovery of some new oil fields and the decline of the former USSR economy also had a great impact.

Since September 2000, oil price has regularly gone up for a combination of reasons: a growth in oil demand, especially from emerging countries (such as China and India), a return to demand growth from transitional countries, for increased transportation fuel resulting from the globalization of the world economy and the under capacity of industrial investments (refineries for diesel, fleets of tankers, pipelines). The growing world oil needs now calls for new production capacities (around 85 million barrels per day). This situation will go on for several years because of the time needed to explore for new supply, drill oil wells and to build refineries. The current oil prices will not diminish in the next five to ten years if the world oil demand remains high.

**We are clearly facing a new oil crisis**. The 2005 oil price was exactly the value of the 1973 and 1985 oil crisis average value. This crisis is important enough to lead to natural gas and coal prices having a parallel increase with oil price.

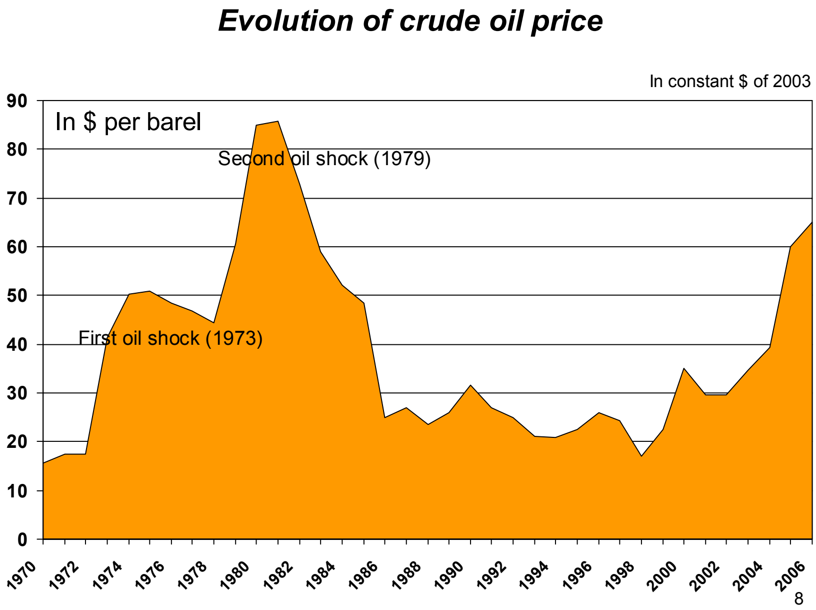


**Figure 1** - Evolution of crude oil price

At the same time some oil fields are clearly becoming depleted (USA, North Sea, Indonesia) and new production increases are having difficulties offsetting the decline of older fields. During the sixties the level of oil discoveries was around 50 billion barrels annually, it decreased in the eighties to 30; the current level is approximately10 (essentially offshore fields). Furthermore, a new debate is now opening on when the inevitable world oil production decline will occur: the new fields will no longer be able to offset the decline of some giant oil fields even in the Middle East. Experts are projecting this decrease to be in between 2010 and 2030 which will cause a great tension –and invariably upward pressure -- on prices.

The obvious conclusion is that oil price will be high during the coming decades and the average value will be unpredictable if adverse political events increase the pressure (Middle East, former USSR). The actual price level of between 60 $ and 70 $ seems to be a long-term base to take into account.

If the whole world will have to cope with these facts, the small Pacific islands, which are dependant on sea transportation and oil, will be faced with an even greater problem. In the case of Tuvalu higher oil prices will also mean an increase of the prices of all goods imported.

## III.2 Vulnerability to climate change

The flat low-lying islands of Tuvalu make this tiny nation the most exposed country to climate change impact. There are three threats acting at the same time: El Nino oscillation more turbulent weather (causing salty water flooding on the islands' soil) and sea level increase (estimated to be between 1 to 6 mm per year in Tuvalu – various references).

Geographical and physical characteristics (e.g. small catchments, tropical storms intensity, cyclone frequency, low lying atolls, etc), makes these islands highly vulnerable to a range of environmental impacts at rates and intensities above those found elsewhere in the world. These include geographic isolation, ecological uniqueness and fragility, rapid human population growth (which seems to have stabilized) and associated waste disposal problems, limited land resources, high dependency on marine resources, exposure to damaging natural disasters, low economic diversification, few export products, exposure to external trade and markets and global changes in climate; all of which contribute to increasing environmental and economic vulnerability.

Tuvaluan society seems to be aware of the climate change threats.

This study's objective is to help Tuvalu find innovative ways of development to reduce carbon dioxide and methane emissions and reduce oil consumption. The identified development solutions are economically, environmentally and culturally sustainable. The future of Tuvalu is clearly bound to the capacity of major industrialized countries to combat climate change. Nevertheless, it is essential to promote Tuvalu as an example of a successful sustainable development process with a low level of GHG emissions.

## III.3 NATIONAL ENERGY BALANCE

Tuvalu's energy consumption is quite difficult to estimate. Data recorded in annual statistics are not gathered from all sources. If there is a clear knowledge of the energy consumption in the electric sector, the other different uses of oil (road, marine and air transportation, cooking…) are not precisely disaggregated. In addition, the non-commercial energy supplies such as biomass are not included at all in the official GoT data.

The Alofa Tuvalu experts worked in three directions:

- To rebuild a comprehensive table including all energy sources;
- To try to give the clearest description of the energy consumption by end-use;
- To undertake a household survey to decipher the amount of biomass and other energy used in the domestic sector.

This effort has produced basic estimates and has highlighted the need for improved government statistics that can be achieved through regular data collection from all sectors (commercial and non-commercial) to be included in the yearly statistical report.

### Tuvalu, an oil dependant society

The primary energy consumption represents the upstream supply. The only national energy source is biomass (18% of total consumption). Photovoltaic and thermal solar contribute for less than 1%. The balance of supply is oil (Fig. 2).

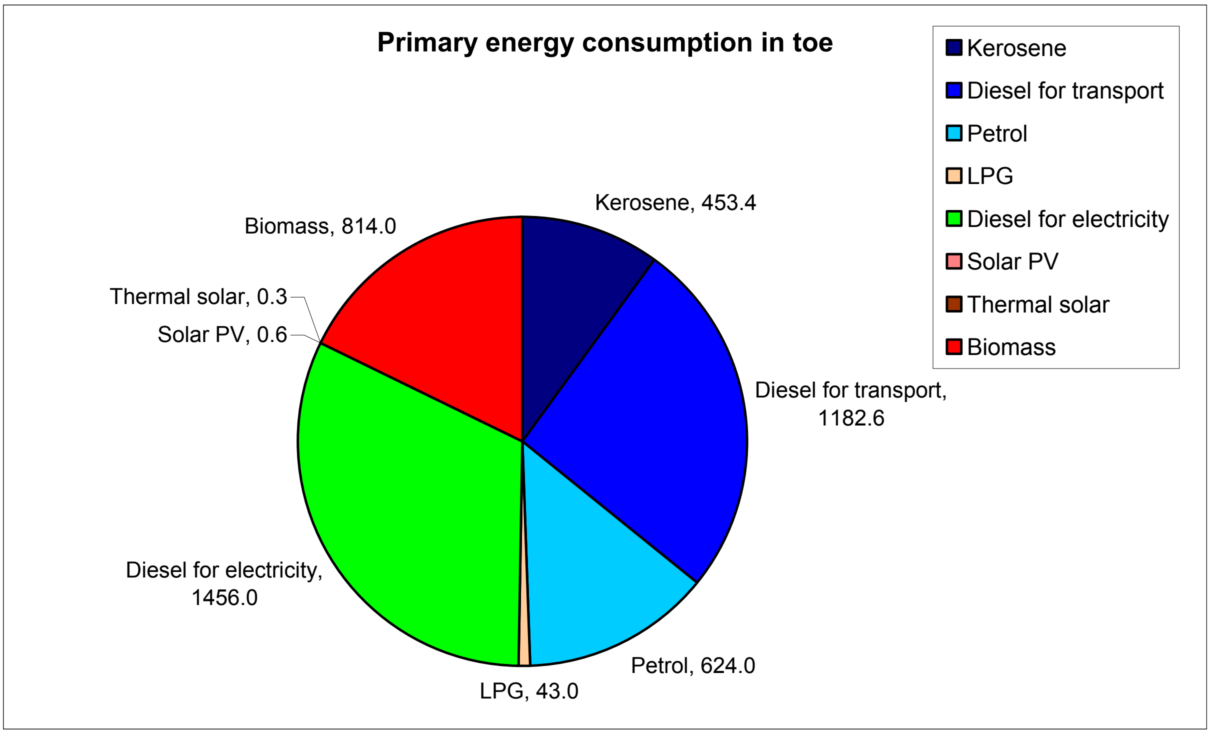


**Figure 2** - Primary energy supply (toe) (data from Annex 1)

Tuvalu is close to being a totally oil dependent economy. In 2004 the total energy consumption was 4.6 ktoe [4], oil accounting for 3.8 ktoe (82%) and biomass for 0.8 ktoe (almost 18% of the total primary energy consumption). This includes diesel charged by the two vessels (Nivaga II and Manu Folau) in Suva, Fiji.

Annual energy consumption is over 0.4 toe per capita (approximately one tenth of someone living in the UK or France). The oil consumption level is non-negligible due to the needs of inter-island transport and electricity generation facilities. Currently, all of Tuvalu's oil is imported - this is a very vulnerable position: increasing oil prices and a drop in global oil production would leave Tuvalu's economy in the hands – and at the mercy - of oil suppliers.

Figure 3 shows the energy consumption end uses in relation to social needs [5]. It clearly shows the predominance of transport, which represents 53% of the total consumption. The second most important end-use is cooking (food and boiling water for drinking) which represents 33% of total consumption.

[4] - toe : ton of oil equivalent ; ktoe = 1000 toe.

[5] - The final energy consumption is calculated by subtracting the energy transformation losses, especially in the electricity generation, from the primary energy consumption.

The third is electricity for specific uses (e.g. lighting, domestic appliances, refrigeration, cooling, etc.) representing 13% of final energy consumption - cooling appliances already account for one third of this category and their use in Tuvalu is growing rapidly [6].

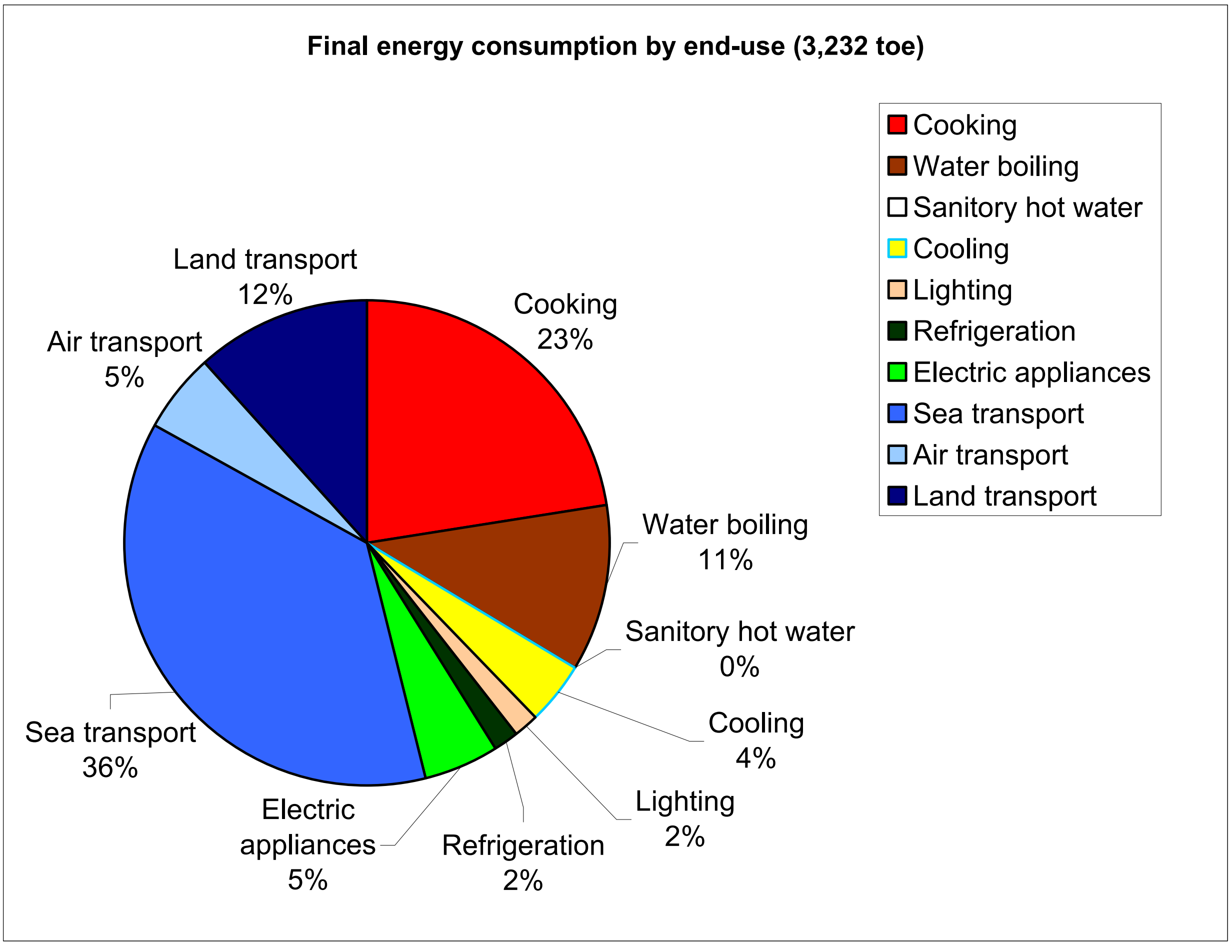


**Figure 3** - Final energy consumption by end-use (3,232 toe)

[6] - These values have been estimated by the experts. One of the study's recommendations is the consolidation of all energy data, to build an energy balance and to include it in the annual economy report.

## III.4 ELECTRICITY CONSUMPTION

Since Tuvalu's electricity generation efficiency is low, around 35%, the significance of the electricity sector is higher in the primary energy balance than in final end-use consumption. Only 3,232 toe (71%) of primary energy supply reached an end-use category. 1,341 toe (29% of primary energy supply) was wasted, mainly due to low electricity generation efficiency.

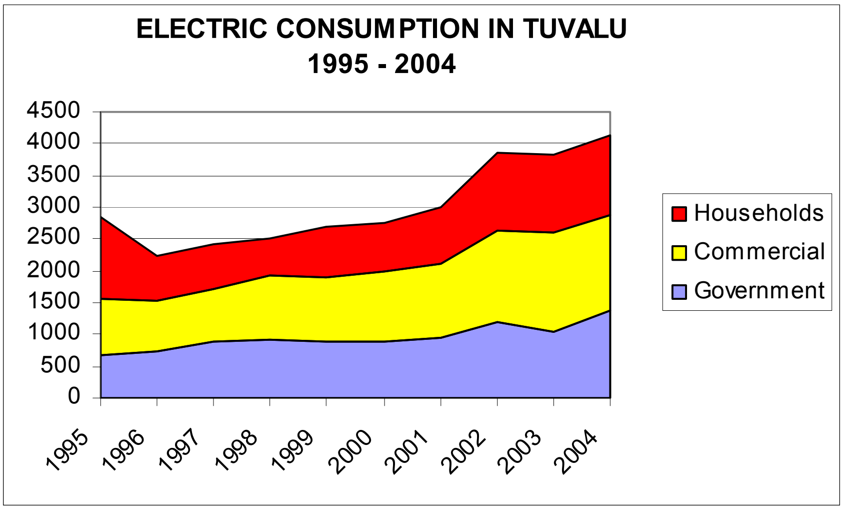


**Figure 4** - Electricity consumption in Tuvalu

Tuvalu's electricity consumption is increasing rapidly at a 3.8% yearly average rate over the last ten years. It reached 4,121 MWh in 2004.

However, because of frequent electricity shortages coming from a rapidly growing demand, especially after the hospital and government buildings opened in late 2003 and late 2004 respectively, a new power station is being implemented on the main island. Funded by Japan Aid, the construction includes 3 new diesel oil-fired electricity generators. The present study on RE could seem redundant unless the option to substitute fossil fuel oil for a renewable resource such as biodiesel in the new power station is accepted by the Japanese project managers and the GoT. The biodiesel option is technically feasible and, whilst still at the planning stage, it might be possible for the GoT to negotiate a larger lubrication oil incinerator than the one planned by Japan Aid in order to burn lube oil from the rapidly increasing number of private vehicles as well as the generators' lube oil. Ideally, this incinerator could also be put to use to create energy.

This new 1800 kW capacity power plant should be operational by the end of 2006. The old generators will then be used as additional security and during maintenance of the new generators. This new capacity will be too large for Funafuti's needs– even at a projected 6% annual electricity demand increase, for one decade. In addition, to ensure that further diesel generation capacity is not required for the foreseeable future, other options could be implemented such as installing PV cells on the roofs of new buildings.

The new generators will have a conversion efficiency of around 40% vs. 35% for the old generators. This increased efficiency will result in a decrease in oil consumption of around 180 toe based on 2004 electricity consumption figures i.e. a reduction of 5% of Tuvalu's global oil consumption.

No new capacity seems to have been planned for the outer islands, apart from a request to the French Embassy in Fiji for some PV systems. It is particularly important to foresee the reinforcement of their supply as outer islands' electricity consumption, with an aggregate similar population, currently represents around 20% of Funafuti's. In 2002, their consumption was only about 13% of Funafuti's use. On Funafuti average annual household consumption is 1.8 MWh, whilst on the outer islands it varies between 0.36 and 0.8 for Vaitupu.

## III.5 Transportation

### *III.5.1 Sea transportation*

Passengers and freight are transported between Funafuti and the others islands by two vessels (Nivaga II and Manu Folau). Their role is vital for the Tuvaluan economy and society: they allow people's movement from island to island and ship imported food and goods, equipment and oil, providing a life-line for the outer islands. These functions need to be managed in a socially acceptable way and it is essential that their costs remain affordable. The consequence of a justified low tariff policy is an endemic accounting shortfall. The actual running costs of the vessels are around three times higher than the income from passenger fares and cargo fees. This shortfall will deepen further with the oil price increase and the outer islands will be hit the hardest.

The two vessels total fuel consumption is around 1160 toe. Oil consumption to go to Vaitupu and back is around 1.2 tons for Nivaga II and 0.9 tons for Manu Folau. Energy consumption from the two ships making the trip from Suva-Fiji - the MV nei Matangare and the MV Southern Moana – have not been considered in the energy balance. These ships supply several countries: Tuvalu, Kiribati, PNG, Wallis and Futuna, New Caledonia, from Fiji. Their cargo for Tuvalu represents approximately 300 containers, 1/3 of which are refrigerated. Therefore, the real weight of sea transportation is only partially included in the country energy balance (Figure 3).

Before the 2000 oil price increases, the cost of oil to power the Nivaga II and the Manu Folau represented one third of total expenditures. Fuel costs alone totally absorb the passenger's fares and cargo fees before paying the crews, insurance and maintenance costs.

Fuel costs are increasing. Crude oil has already tripled since 1998 [7] and the trend continues upward. This puts Tuvalu in a very difficult situation and the outer islands will be hit hardest by future price increases.

Currently, Tuvalu does not have the capacity to deal with further price increases for imported oil: increasing the vessels energy efficiency could be an option, but the social need for an affordable transportation service for passengers and freight is an absolute priority for politicians and decision makers. One excellent option to be seriously investigated is the replacement of imported oil by another fuel from biomass such as a copra biodiesel (a proven technology option).

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[7] - At the time of the field study (August 2005), the repercussion of this increase has not been completely applied to the prices paid by Tuvalu.

### *III.5.2 Road transportation*

In 2004 road transportation accounted for 12% (380 toe) of Tuvalu's final energy consumption, 3% (78 toe) of total diesel imports and almost 50% (302 toe) of imported petrol. Since the introduction of tarmac roads in Funafuti, the use of fossil fuel powered vehicles has rapidly increased.

The outer islands have no tarmac roads so the number of vehicles is much less than in Funafuti. Tarmac roads are a requested priority for the outer islanders – particularly Vaitupu. However, if roads are developed further without changes in the existing vehicle legislation, the resulting increase in cars, trucks and motorbikes will create major problems for Tuvalu. Since the country is almost 100% dependent on imported oil for essential sea transportation and electricity generation, oil resources will come under pressure as the number of vehicles increases further. At the pump fuel prices have made a jump of around 50% from September 2005 to January 2006.

In addition, many types of road vehicles being imported into Tuvalu are totally inappropriate for local conditions. Given Funafuti's flatness, with approximately 14 km of road with several speed-humps per km, gas-guzzling vehicles with a capacity of more than 200 km/h and 4x4 vehicles are not required. GoT legislation gives no guidance as to engine size, emissions, fuel efficiency or safety of imported vehicles. This situation needs immediate attention.

### *III.5.3 Air transportation*

Air transportation accounts for 37% (170 toe) of total kerosene imports (453 toe). The amount of fuel used for air transportation has remained fairly constant over recent years [8]. There are three weekly flights between Fiji and Funafuti. The remoteness of the country and other factors have discouraged any tourism increase (less than 100 tourists a year out of approx 1000 visitors in 2004 – Alofa Tuvalu survey 2004).

## III.6 DOMESTIC ENERGY USE

In 2004, a total of 1170 toe (36% of total national energy consumption) was used for domestic purposes, 91% of it (1070 toe) was for cooking & boiling hot water. Biomass provided 64% (746 toe) of total domestic energy use, kerosene 23% (263 toe), electricity 10% (118 toe), and LPG 4% (43 toe). Solar energy provided 0.6 toe mainly for lighting & electrical appliances [9].

### *III.6.1 Commercial Energy Use*

In 2004, a total of 218 toe (7% of the total national energy consumption) was used for commercial purposes; 60% of it (130 toe) was for electrical appliances. Biomass provided 31% (68 toe) of total commercial energy use (coconut oil production for cosmetic uses – outer islands Kaupule projects)[10],

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[8] - Kerosene imports do not seem to be included in the quarterly financial documents. Purchase is made by Air Fiji, of which Tuvalu is a main share holder. However, the figures quoted here may be low as some of the kerosene purchased might be accounted for by BP/AIR FIJI's yearly balance rather Tuvalu's national accounts.

9 - These values have been estimated from the survey carried out by the Alofa Tuvalu team (July-September, 2005). Despite biomass providing 18% of Tuvalu's total primary energy, it has thus far failed to be recorded in Tuvalu's official government statistics. Because the situation is highly variable from island to island and even from one family to another, a regular survey is needed. Habits are rapidly changing in this sector and it is where local resources, mainly biomass and solar, can contribute further to reduce external dependency.

[10] Again, commercial biomass energy use failed to be recorded in official GoT statistics.

kerosene provided 9% (20 toe), electricity 60% (130 toe). Solar PV did not provide any electricity for the commercial sector – despite the fact that the BP oil storage facility has a solar PV installed. This equipment remained unused as existing GoT legislation states that the Tuvalu Electricity Corporation (TEC) must supply all electricity.

### *III.6.2 Public Sector Energy Use*

In 2004, a total of 106 toe (3% of the total national energy consumption) was used for public services; of this, 100% was for electrical appliances. Interestingly, 63% (67 toe) was for cooling appliances, presumably for the new GoT building which opened in July 2004 and appears not to have been designed with energy efficiency as a primary concern. Solar thermal provided 0.3 toe for heating sanitary hot water for use at the hospital.

## III.7 Trends in Energy Use

It clearly appears that the Tuvalu's energy consumption is divided into three parts:

- ***Thermal purposes (cooking, boiling drinking water, and sanitary hot water).***

It is the only area where energy sources are competing. Two kinds of energy sources provide the majority of thermal energy: oil (kerosene) and biomass (traditional use of wood, coconut husks). Electricity also provides a small amount of thermal energy. Because of the lack of data concerning biomass, the importance of such needs (35% of total final energy consumption) is underestimated in official GoT statistics. There is a huge potential for energy efficiency improvements (improved cooking stoves) and further progress towards RE substitution for kerosene and electricity (solar water heaters and cookers and biogas).

- ***Specific uses of electricity (lighting, refrigeration, cooling, domestic appliances and electronics)***

The specific uses of electricity represent 9% of the final energy consumption [11]. They are increasing rapidly and currently almost completely depend on electricity generation from imported oil.

- ***Transportation***

Here too, all the supply is dependent on only one source of energy: imported oil. All kinds of transportation represent 53% of total national energy consumption.

These trends reveal several priorities for Tuvalu's energy policy:

- To increase and modernise the thermal uses of renewable energy resources,
- To promote renewable energy sources for electricity generation,
- To reduce the dependency on imported oil for transportation.
- And, in all cases, to reduce use by improving energy efficiency.

[11] - The same value calculated in primary energy gives 35 % of the total energy supply.

# IV RENEWABLE ENERGY POTENTIAL: TUVALU'S INDIGENOUS ENERGY RESOURCES

## IV.1 Biomass Energy Resources

Data and information for biomass energy use and availability was gathered during a survey carried out by the Alofa Tuvalu team (July-September, 2005).

### *IV.1.1 Sustainable biomass use does not contribute to climate change*

One opening comment has to be made: as with all combustion processes, burning wood or other biomass materials emits carbon dioxide. However, through the process of photosynthesis, a plant, during its growth phase, absorbs carbon dioxide from the atmosphere. Therefore, if the use of biomass as a fuel does not diminish the total stock of biomass, its use can be considered as a net zero $CO_2$ emission process. This study only considers sustainable use of biomass energy for Tuvalu. In addition, by using biomass energy instead of fossil fuels, GHG emissions will be reduced overall.

### *IV.1.2 Current Biomass Energy Use & Availability of Unused Residues in Tuvalu*

The total number of coconuts used to feed the pigs and the people is 6,672,361 per year. The energy available from these coconuts' husks and shells is 52,044GJ or 1,239 toe.

The total number of coconut husks used as a fuel (domestic & commercial) = 5,136,242 (with an energy value of 20,545GJ or 498 toe).

The total number of coconut shells used as a fuel (domestic & commercial) = 2,965,101 (with an energy value of 11,267GJ or 268 toe)

From the available husks and shells, the total use as a fuel (domestic) = 31,350 GJ (746 toe) (useful energy after some conversion to charcoal = 26,112 GJ or 622 toe)

Total biomass energy consumption (commercial) = 2,856GJ (68 toe)

| Total number of shells unused each year | Energy value of unused shells | Energy value of shells | Total number of husks unused each year | Energy value of unused husks | Energy value of husks | **Total energy available from unused husks & shells** |
|---|---|---|---|---|---|---|
| | $GJ.yr^{-1}$ | toe | | $GJ.yr^{-1}$ | toe | $GJ.yr^{-1}$ |
| 3,707,260 | 14,088 | 335 | 1,536,118 | 6,144 | 146 | **20,232 (482 toe)** |

**Table 1** - Energy currently available from unused husks & shells in Tuvalu

Vaitupu alone has 176 toe of unused husks & shells, Funafuti 117 toe and the remaining outer islands have 188 toe. However, at the moment, the majority of this organic waste is tipped on sites set aside by the Kaupule and on illegal sites (see *4.1.5* below), less than 20% is composted as only 6-19 % of respondents of the Alofa Tuvalu household questionnaire had family vegetable gardens, 6% in Vaitupu and 19% in Funafuti. Breadfruit leaves & banana skins make up the majority of composted organic material.

### *IV.1.3 Estimate of coconut production in Tuvalu*

From table 3 it appears that coconut production in Tuvalu is enough to easily meet requirements for current domestic & commercial biomass energy needs as well as current indigenous food uses. In addition, if appropriate steps are taken, current biomass production could also supply 56% of current annual fuel requirements for the outer island boats. The boats use half the total fuel oil imported into Tuvalu. Therefore, current coconut productivity in Tuvalu could easily replace 25% of current total fuel oil use. Payment to copra growers would total A$ 575,093 annually at prices currently agreed with producers on Vaitupu (0.4 A$ per kg or world market price). However, the highest tonnage of copra supplied to Tuvalu Copra Trading Cooperative was approximately 850 tonnes per year, which is 50% of the estimate in the table below. **This would suggest that copra production is not constrained by the resource available but would be constrained by the amount producers were able/willing to collect and process.** Before the collapse of Tuvalu's copra industry in 2003, an average of only around 200t per year was being cut. On visiting Niulakita and Neukalaelae, (March 2006), Alofa Tuvalu personnel noted that the bush previously used for copra production had become overgrown and would require clearing before copra production could commence again.

| *Total number of hectares under coconut | Estimate of total number of productive trees | Estimate of total number of trees over 60 years | Total coconut production | Number of hectares requiring re-planting | **Theoretical availability of coconuts for biomass energy production |
|---|---|---|---|---|---|
| ha | trees | trees | nuts per year | ha | nuts per year |
| 1,524 | 267,760 | 68,929 | 14,141,100 | 391 | 7,468,739 |

**Table 2** – Coconut production in Tuvalu

- Source: Based on Dept. Lands & Survey, 2004 – data from 1986-88; McLean & Hosking (1991) and Seluka *et al* (1998); Alofa Tuvalu survey, 2005.

Total production minus use. As the age of the coconut tree increases above 45 years, its productivity begins to decline.

| Total number of litres of oil per year | Energy value of coconut oil | toe of oil produced | *Copra production | toe of the copra produced | % of boat fuel replaced by coconut oil |
|---|---|---|---|---|---|
| $l.yr^{-1}$ | $GJ.yr^{-1}$ | toe | $t.yr^{-1}$ | toe | % |
| 777,184 | 26,168 | 623 | 1,643 | 39 | 56 |

**Table 3** - Theoretical production of coconut oil from unused coconuts in Tuvalu

* This estimate is based on coconut production per productive tree in Tuvalu and is more conservative than the figure for copra production of 1.2t/ha used by Trewren (1984)[12]. However, it is less than Trewren predicted if you use is figures of 215 trees/ha; 60 nuts/tree & 0.187 kg copra/nut.

### IV.1.3-b Estimate of coconut production in Vaitupu

The replanting scheme in Vaitupu (1970-1984) was made at a density of 270 trees per ha (a spacing of 7.32 m), although the limited Alofa Tuvalu survey observed a planting density of approximately 180 trees/ha and 50 nuts/tree/yr. Turning trash into compost for replanting was encouraged in the 1970's scheme and is thought to be responsible for the high success rate of seedling trees and the high productivity of Vaitupu's coconuts. In 1984 it was recommended that 35 ha per year should be replanted across Tuvalu's entire area to replenish and assure future coconut supply. For Vaitupu this represents an area of 9 ha/yr to be replanted. However, it is now over 20 years since the subsidised scheme finished so major replanting is necessary to replenish and maintain coconut productivity to reach sustainable levels.. The Alofa Tuvalu survey (2005) indicated that around 16% of respondents had carried out some replanting on their land. Based on this, an estimated 135 ha in Vaitupu requires immediate attention – not including the diseased coconut trees in the village areas.

| *Total number of hectares under coconut cultivaation | Estimate of total number of productive trees | Estimate of total number of trees over 60 years | Total coconut production | Number of hectares requiring re-planting | **Theoretical availability of coconuts for biomass energy production |
|---|---|---|---|---|---|
| ha | trees | trees | nuts per year | ha | nuts per year |
| 408 | 73440 | 24235 | 3672000 | 135 | 2103680 |

**Table 4** - Coconut production in Vaitupu

* Source: Based on Dept. Lands & Survey, 2004 – data from 1986-88; McLean & Hosking (1991) and Seluka *et al* (1998) – Cited in Lands & Survey 2004. Alofa Tuvalu survey, 2005. ** Total production minus use. As the age of the coconut tree increases above 45 years, its productivity begins to decline.

| Total number of litres of oil per year | Energy value of coconut oil | toe of oil produced | *Copra production | toe of the copra produced | % of boat fuel replaced by coconut oil |
|---|---|---|---|---|---|
| $l.yr^{-1}$ | $GJ.yr^{-1}$ | toe | $t.yr^{-1}$ | toe | % |
| 218905 | 7371 | 175 | 463 | 309 | 16 |

**Table 5** - Theoretical production of coconut oil from unused coconuts in Vaitupu

This estimate is based on coconut production per productive tree in Vaitupu and is more conservative than the figure for copra production of 1.2t/ha used by Trewren (1984)[13].

[12] Trewren, K. (1984) Coconut Development in Tuvalu. Ministry of Commerce & Natural Resources, Funafuti, Tuvalu.

[13] Trewren, K. (1984) Coconut Development in Tuvalu. Ministry of Commerce & Natural Resources, Funafuti, Tuvalu.

Copra cake (the remains of the copra after crushing for oil) is a good food for pigs and chickens. From the above copra production an estimated 139 tonnes of copra cake would be produced. This could be sold at 0.10 A$.kg$^{-1}$ to raise an additional A$13884.

The majority of unused husks and shells go to landfill, creating a large portion of organic waste. Alofa Tuvalu (2005) estimated the proportion of organic waste in the unofficial dump at the north end of Funafuti to have an energy content equivalent to 403 toe. This result ties in closely with that available from unused husks and shells (detailed in the table above). This is a resource that could by gasified and used for electricity and sanitary hot water production.

### IV.1.4 Estimate of Unused Pig Waste for Biogas in Tuvalu

Domestic kerosene use in Tuvalu was estimated at 263 toe annually, which is considerable when compared with 170 toe for air transportation (see Annex 1 below). The use of biogas as a fuel for cooking should reduce kerosene use. In theory biogas could be produced from the unused pig waste (see section V – Adoption of renewable energy alternatives in Tuvalu). Another rich potential source is human waste which has not been taken into account in this study.

Apart from fishing, Tuvalu's food and life is based around raising pigs. Households own in between 3 and 20 pigs. In Funafuti, pig pens are scattered along 10 kms, of an island whose total length is 14km, a long ribbon of narrow land, 500 meters at it maximum width - if we include ponds and borrow pits. These pig pens create waste which is unused and pollutes an already very vulnerable environment. Today many Tuvaluans - including the GoT which is currently backing a national piggery project - are aware and ready to act. However, there are still barriers to be overcome – will people be willing to house their pigs far away from there homes, land tenure issues, etc - and lessons to be learn from the Tuvalu Model Piggery/AusAid experience. (see V)

| Total number of pigs | Total annual production of pig manure | Total annual theoretical production of energy from pig manure | Total amount of manure available annually for use in biogas digester* | Total amount of energy available annually for use in biogas digester* |
|---|---|---|---|---|
| head | t.yr$^{-1}$ | GJ.yr$^{-1}$ | t.yr$^{-1}$ | GJ.yr$^{-1}$ |
| 12,328 (60%=7,397) | 3,600 | 32,400 (771toe) | 2,106 | 19,440 (463 toe) |

**Table 6 -** Energy currently available from unused pig waste in Tuvalu

*Assumes 60% collection efficiency as some waste is used for compost and some will be difficult to collect.

### IV.1.5 Other waste resources

A major study was financed by the ADB and undertaken by Tony Kortegast/Tonkin & Taylor over 2 years. (see Annex V) After a change of management within ADB, the implementation of the study's findings was halted late in 2005. While finalizing this present RE study in Tuvalu, we have been made aware that another study is on its way, financed by UNDP.

The landfill site set up by AusAid in 2000 which is much too small to receive any waste such as vehicles or equipment, other than household's, is no longer viable since the bulldozer broke down. Waste cannot be moved around the site which is overflowing into the road. This has led people to tip their waste illegally – in an unofficial waste tip at the north end of the main island. Both the Tonkin & Taylor and the Alofa Tuvalu survey found the tip consists of approximately 70-80% organic material including coconut husks and shells which, as mentioned above, is a suitable feedstock for energy production that is currently literally going to waste.

| Total area covered by the site $m^2$ | Total volume of waste $m^3$ | Volume of organic waste $m^3$ | Energy content of organic waste GJ | Energy content of organic waste toe |
|---|---|---|---|---|
| 8375 | 3255 | 2,116 | 16926 | 403 |

**Table 7** - Municipal Solid Waste – Alofa Tuvalu survey results for the unofficial dump at the north end of the island

## IV.2 Wind Energy Resources

- **Funafuti's wind potential**

The meteorology station has results from wind speed measurements on 4 islands from 1949 to date.. For this preliminary study, only Funafuti's records were analyzed.

They show an average wind speed of around 9.16 knots (nautical miles per hour) for the period from 1950 to June 2005[14] inclusive, i.e. 4.72 meters per second [15].

Two additional aspects have to be taken into account:

– The anemometer of the met station is 10 m high surrounded by coconuts with a similar height; windmill masts are at least 30m high, so readings must be gathered at this height, , at which it is likely that higher (i.e. more usable) windspeeds would be revealed;

– The site chosen for measurement, which is close to the airport, does not have the best potential for wind. – to be accurate; measurements must be taken close to the potential site for the wind turbine.

[14] - For the period July 1996 - December 1998, records have yet to be put into a computerized form. The graphs have been built with 123,000 records from 1950 to mid 2005. The spreadsheet created for the purpose of this study has been passed on to the met office. This 9.16 knots value includes high speed wind too violent to produce electricity. Therefore this gross value is not the real one and cannot be used to estimate the actual usable wind energy potential.

[15] - 1 nautical mile = 1853 m. 1 knot = 1853/3600 (3600 $s.h^{-1}$ = 0.515 $m.s^{-1}$.

One can reasonably consider that a better location with a height equivalent to that of the projected wind turbine will give a 6% better result. Therefore the real value would be 5 $m.s^{-1}$.

Normally, an average wind potential of more than 7 $m.s^{-1}$ is considered to be economically exploitable for wind energy.

The average annual speed can vary from 3.4 and 6.5 $m.s^{-1}$. The following graph (figure 5) gives details of the different wind speeds. The wind speed records for the whole period (1950- mid 2005) have been classified in increasing order (x axis).

This graph clearly shows four kinds of situations:

– 60% of the time, the wind is exploitable (between 9 and 42 knots or 4.5 and 21 $m.s^{-1}$) and the average speed for the portion able to produce electricity is 6.9 $m.s^{-1}$. A 10 knots speed is the most frequent in this portion which is exploitable for electricity generation.

– 8% of the time, there is no wind at all and 32% of time, it is too weak to drive a wind turbine.

– At the opposite end of the scale, when the wind exceeds 42 knots, the wind turbine cannot exploit the wind without an excess of power. The most violent winds recorded in the last 55 years were close to 100 knots (180 $km.h^{-1}$, cyclones). The wind turbine would have to be laid down on the floor in these conditions. Turbines which can be easily decommissioned in this fashion during high winds are readily available

**The final value of actually exploitable wind to be taken into account for the entire year is 4.14 $m.s^{-1}$. When it blows enough, its average speed is 6.94 $m.s^{-1}$.** This average potential is weak and intermittent.

With the wind being irregular, rapidly changing, and violent, and with an average speed of less than 4.5 $m.s^{-1}$ it would need to be integrated into a grid (see below) with a security source which can be stored, such as diesel/biodiesel generation system or another source of renewable energy. However, the economics of Tuvalu's wind potential still can be favourably compared with oil fired electricity generation costs.

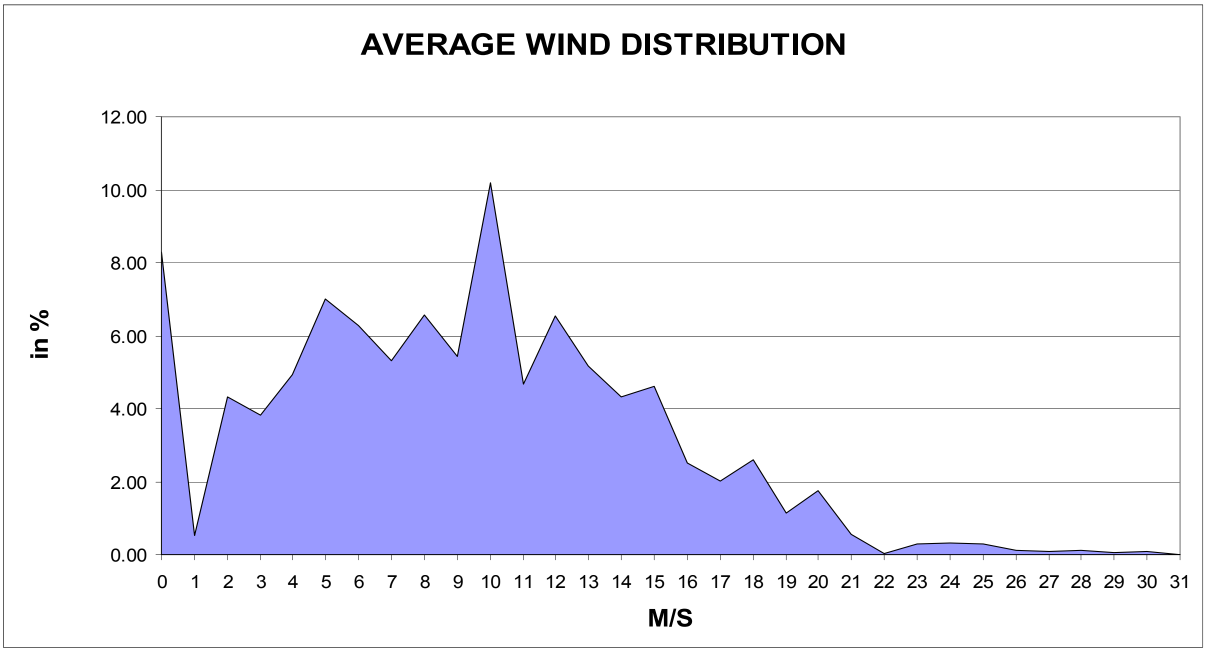


**Figure 5** - Average wind distribution

The same kind of wind analysis can be completed with the met office to get the wind generation potential for the outer islands which we have been told is higher on southern islands. This report strongly recommends that appropriately sited wind measurements be taken for at least one year in order to accurately assess the potential of wind power on the outer islands.

- **Technologies available to implement**

Wind energy was first developed by Danish manufacturers for their domestic use and in California ('80s). More recently, the market has largely expanded in Germany and Spain. These countries now count as the major manufacturers, especially for units of greater size. The experience of wind energy now covers a wide number of countries: Europe, India, China, Morocco, Caribbean area, Canada, US, etc. It is a well demonstrated and developed technology which is now much cheaper than comparable oil-fired generation systems when applied under the correct wind conditions.

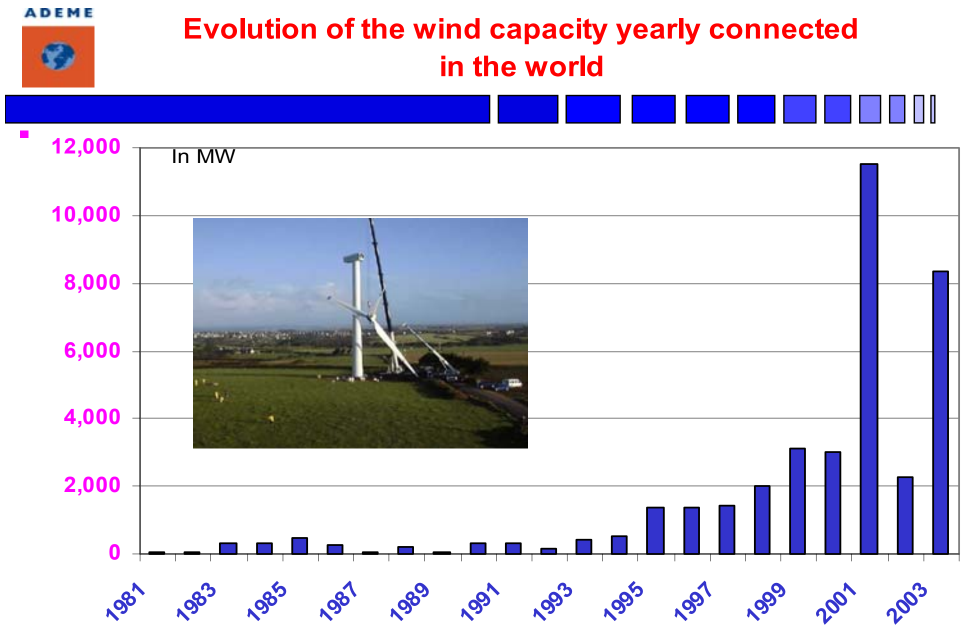


**Figure 6** - Evolution of wind capacity yearly connected in the world

It is only since the beginning of this decade that wind energy achieved a real industrial market status opening the way to decreasing wind generation costs (figure 6).

This energy is now a mature technology providing machines with a wide range of capacities (from 10 kW to 5,000 kW for offshore wind farms).

However, there is still little experience in the Pacific area. The first unit (20 kW) has been built at the Suva SOPAC office by a French manufacturer, Vergnet, who specialises in wind mills for tropical conditions. The Fijian site has been chosen essentially for training purposes and the location has poor wind potential.

If wind turbines are to be installed in Tuvalu, sites and designs have to be chosen carefully because of the specific conditions (the windmills would need to be constructed with rust and salt corrosion–resistant materials, and be designed to withstand cyclones (i.e. they must be easy to lay down in less than one hour).

For Funafuti the suitable size for a first unit would be around 270 kW and between 10 and 50 kW for each of the outer islands. A 200 kW windmill is 55 m high with a blade diameter of 32 m. Annual production per 270 W unit would be around 316 MWh (which corresponds at nominal capacity to an operational duration of 1230 hours per year).

The sites would have to be chosen precisely -according to prevailing winds, in a position with as few obstacles as possible such as coconuts trees, far enough from houses and the airport. Furthermore, the site has to be accessible for connection to the grid and maintenance.

Maintenance needs for this technology are rather low as there are no elements to replace regularly.

- **Integration of wind energy in the grid in an hybrid concept**

Considering Tuvalu's conditions and planned future electricity generation, this hybrid system represents Tuvalu's best option for wind energy. In an integrated system the management of the grid has to follow an order of merit:

First: Use the wind turbine when the wind is sufficient,
Second: Use solar PV or bio-fuelled electricity generation, and
Third: the conventional mineral diesel oil fired engines.

There are three reasons for this: to give priority to renewable over fossil fuels for environmental and economic reasons; it decreases the cost of imported oil; and it improves Tuvalu's fuel security.

Development of wind energy offers another opportunity to Tuvalu: to tackle the important issue of water supply. When the supply of electricity exceeds the demand, the additional capacity can be used for water desalinization or water purification.

- **Economics**

In industrialized countries with a 6 $m.s^{-1}$ per year average wind, the cost per kWh is now 0.07 € [16] (0.11 A$) – including purchase price of the generation equipment. The cost per kWh has historically declined by 5% per year on average. That corresponds to a yearly 2000 hours operation duration at nominal capacity. As industrialization is increasing, cost is on a decreasing slope to get to 0.05 $€.kWh^{-1}$ in 2015 i.e. less than 0.07 A$ per kWh.

The investment cost of a wind turbine is around 2,500 A$ per kW including installation costs. That gives roughly an investment of 675,000 A$ per 200 kW unit and 25,000 A$ for a 10 kW.

[16] - Applied exchange rate: 1€ = 1.2 US $ ; 1 US $ = 0,85 A$ therefore 1 € = 1.4 A$.

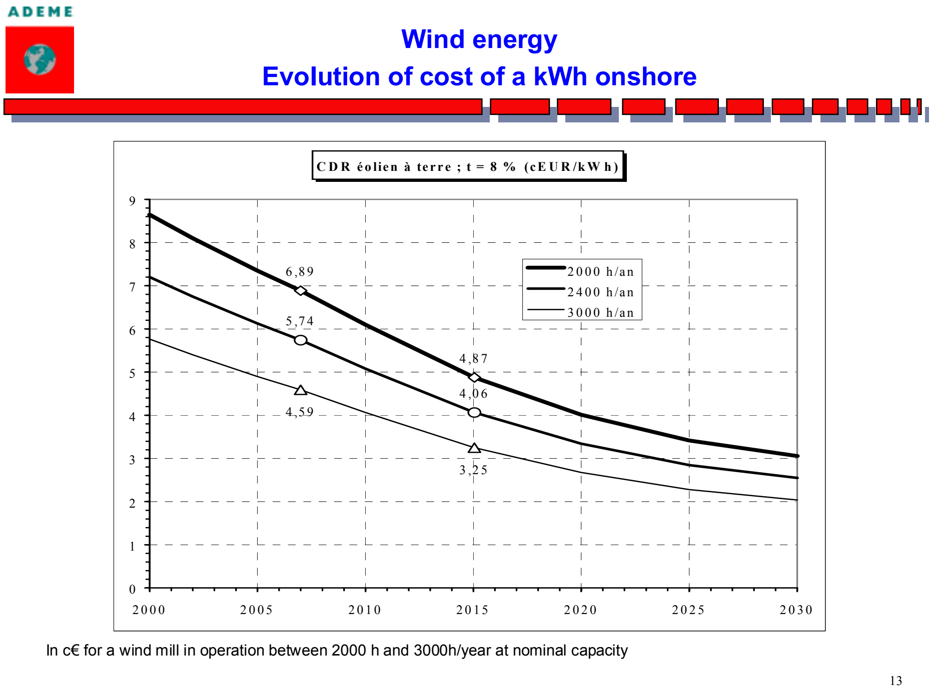


**Figure 7** - Evolution of cost of a kWh onshore

Because of shipping cost, technology adaptation for tropical violent winds and salty air, the learning phase related to a new technology in the region and additional construction costs (a special crane has to be shipped), the cost will be higher for Tuvalu.

A 200 kW wind turbine requires 2 containers of 40 feet + blades [17]. The final estimated cost to take into account is 800,000 With an assumption of 1200 hours functioning per year, and 20% of operating and maintenance cost, it comes to 0.23 A$ per kWh.

This total cost includes the initial investment (before any donor subsidy), operating costs (employment), monitoring and maintenance, all of which were calculated with a discount rate of 5 %.

Two additional considerations have to be kept in mind for Tuvalu's national interests:

– Maintenance and operating costs are low. The life span is now more than 20 years in offshore conditions similar to those in Tuvalu. It accounts for 20% of the investment for the life span (for insurance, regular maintenance, repair, spare parts and administration).
– Investment: if this is largely covered by international aid, operating conditions have the advantage of avoiding imports and reducing running expenditures.

Both considerations have to be examined separately and more study will have to be done for finer economic analyses, but it is evident that if donor aid covered initial investment costs, then the cost per kWh would be reduced significantly (see the Second Case below).

[17] - Transportation cost taken into account equals 3 containers at 5000 A$ each, for a Suva/Funafuti trip, namely, a 15 000 A$ additional cost.

**First case**: considering the global common interest. The kWh price calculated from the **total** costs for diesel-fired electricity generation, without any external support, gives an average cost of 0.43 A$ per kWh for household and commercial use. The kWh production cost for wind energy based on actual experience in similar conditions to Tuvalu, considering **total** costs, without any external support, gives an average cost of 0.23 A$ per kWh (see above) - half the price of electricity currently sold in Tuvalu. This economic interest is clear.

**Second case**: considering the GoT's financial situation. This price scenario is calculated by taking into account donor aid for the initial investment costs for an oil fired generator and for a wind turbine. The actual diesel electricity generation technology running cost considering only the diesel burnt is 0.24 A$ [18]. The operation and maintenance cost of a wind turbine, under the same donor conditions, are around 0.04 A$. In Tuvalu's case, operational costs for wind generation are eight times less than those for diesel generation!

So, the economic interest for wind energy in Tuvalu is real:

– The total cost for wind, including installation, is lower than the present diesel generation fuel running costs only;

– With an international donor engagement, the investment is largely reduced so wind becomes increasingly economically attractive for Tuvalu;

– The wind energy cost is not dependent on the international energy context so will increase fuel security and general economic strength and independence.

- **Recommendations for implementation**

To implement a wind energy project and obtain positive interest from the international institutions, the usual schedule to follow is outlined below:

– One year additional measurement phase on the planned sites in conditions as close as possible to operational conditions. This will refine the wind data already available. Analysis of these measurements will also define the precise sizing of the installation required and help in accurately calculating the expected electricity production.

– It is essential to take wind measurements on the outer islands at the correct height and site of proposed installations.

– Once measurements have been taken, appropriate sites selected and agreed on, once grid connection technical studies have been completed, a call for tender with a "build and operate" (BAO) contract can be announced. A BAO contract will ensure that the manufacturer's knowledge of conditions of use and maintenance will optimise management performance and reduce costs.

[18] - The quantity of oil required to produce a kWh on Funafuti is 0.28 per litre at a price of 0.86 A$ per litre (August 2005). The kWh cost just for fuel is 0.24 A$. Unfortunately this cost will increase in the coming years when the oil contracts will take into account the latest increase of world market oil price: more than 60 US$/bl in July 2005. In comparison, the wind turbines kWh cost will stay stable. To the oil cost has to be added to other expenditures such as employees, production maintenance and in all cases, distribution cost to deliver electricity to the clients (grid management, consumptions following, bills emitting, accountancy…).

– There will also be parallel links to a Tuvalu-based service provider. Training of key TEC personnel will need to be in parallel for TEC to be able to manage the project into the future.

– Construction could take place as early as a year after having obtained the financing and administrative authorizations – i.e. once studies are complete.

– Assembling the wings, the nacelle and the electric turbine on the tower with special cranes (which would have to be brought to Tuvalu) takes less than a week after laying foundations.

## IV.3 Solar Energy Resources

### *IV.3.1 Solar Photovoltaic*

Tuvalu has a long history of photovoltaic use for decentralized electricity production. The first program was developed in the early 1980's. Considering the pioneering nature of this technology two decades ago Tuvalu's success was relatively good.

However, the many difficulties it had to face have to be analysed and lessons learnt.

- **Lessons learnt from past experience with photovoltaics:**

  - ***On technical choices***

– In the early 1980's, solar technology was not a mature technology. Photovoltaic development was chosen because it was then one of the few ways available to provide people in the outer islands with electricity as there was no grid.

– The pioneering nature of the project meant that there were problems with the reliability of batteries and inverters, which affected the reliability and life-span of the entire unit even though the panel modules themselves were reliable. This unreliability was increased because no clear printed instructions for ongoing use and maintenance were provided in the Tuvaluan language.

– Materials were not chosen to resist rust and salty atmospheric conditions so corrosion of materials was also a problem.

  - ***On management process***

– The initial choice of making the households pay 50 A$ for the installation and a 6.25 A$ monthly fee to ensure further maintenance and replacement expenditures was at that time well in advance of management practices the world over for similar projects. It is now clear that a monetary contribution by every family even at a low level might help people to take care of the system. This approach has been copied throughout rural Sub-Saharan Africa with some success, so Tuvalu's innovative approach is to commended.

– After this good start, the first management mistake seems to have resulted from needing to ask donors to cover the elements replacement cost after the normal life-span of the equipment. The money collected from the beginning of the project only covered salaries and Tuvalu Solar Energy Cooperative Society (TSECS) administrative costs – it was not enough to pay for replacement units which were not included in their prior financing plan. As this kind of expenditure is not the international donor's responsibility, they did not pay. Therefore many households had to stay without electricity for several months or years. Finally, some donors such as the EU agreed to replace the first generation PV equipment.

– It was also not clear at the beginning of the project that there would be future increases in electricity needs for a family, so installed system capacity turned out to be too low. The panel modules installed were 50 Wc each. Therefore, after basic needs such as lighting, radio or some small domestic appliances were fulfilled; additional requests emerged especially for refrigeration. The delivered power level was unable to satisfy the demand.

– In principle, the choice of a specialized company (TSECS) to run the program was sound but unfortunately a management fault occurred at the worst time: when some elements had to be replaced, especially the batteries.

– PV electrical production is still managed by a Tuvalu Electricity Corporation (TEC) affiliate or department, with an analytical accountancy which would allow the service provider to follow membership and running payments in one hand and equipment replacement expenditures on the other, which appears to be a more satisfactory solution.

- ***On economy***

– PV technology had and still has quite expensive installation costs. This has sometimes bent the choice to cheap components with a short life span which further increased costs in the long run as well as the quality of service. Cheap components such as bulbs are not as reliable as quality-assured and more reliable, but more expensive counterparts – as has been demonstrated by the poor performance of cheap bulbs in Niulakita (Alofa Tuvalu, March, 2006).

– After more than 20 years most of the equipment was out of order when given the option to connect to the grid (using diesel electricity generation) most of the outer islands families, with the exception of those in Niulakita, accepted.

- **Today's state of the art**

Progress has been made over the last 20 years - essentially concerning the stability of components:

– Quality of system elements, particularly batteries, has improved.

– Costs are decreasing stemming from the competition from Japanese and German large scale implementation programs.

Some obstacles have not been overcome:

– Efficiency remains low - only around 14% of solar radiation hitting the PV panel is converted into electricity;

– The low capacity of PV panels drastically reduces the effectiveness of supplying the needs of an off grid installation; in practice, major professional uses such as cooling and cooking cannot be met realistically.

– The capacity to store electricity remains weak.

The solar radiation received on earth annually is around 6000 times the world's current energy consumption, but the implementation of solar energy strategies remains complicated and relatively expensive.

Economic conditions do not allow for a quick expansion of photovoltaic electricity: the actual price of a kWh delivered by solar panels connected to the grid comes to around 0.64 A$ on the world market.

As shown in the following graph (Figure 8) the cost will decrease to approximately 0.35 A$ within ten years as the technology will be produced on an industrial scale. This will correspond to an investment price of 1.6 A$ per Wp [19] of capacity. A higher investment cost has to be expected for Tuvalu because of shipment, specific constraints on materials and training. However, as with wind generation, with the help of bilateral or multilateral donors for investment and the same type of GoT subsidies as with current actual electricity distribution, the cost for solar electricity can be cheaper for the Tuvaluan people than fuel generated power.

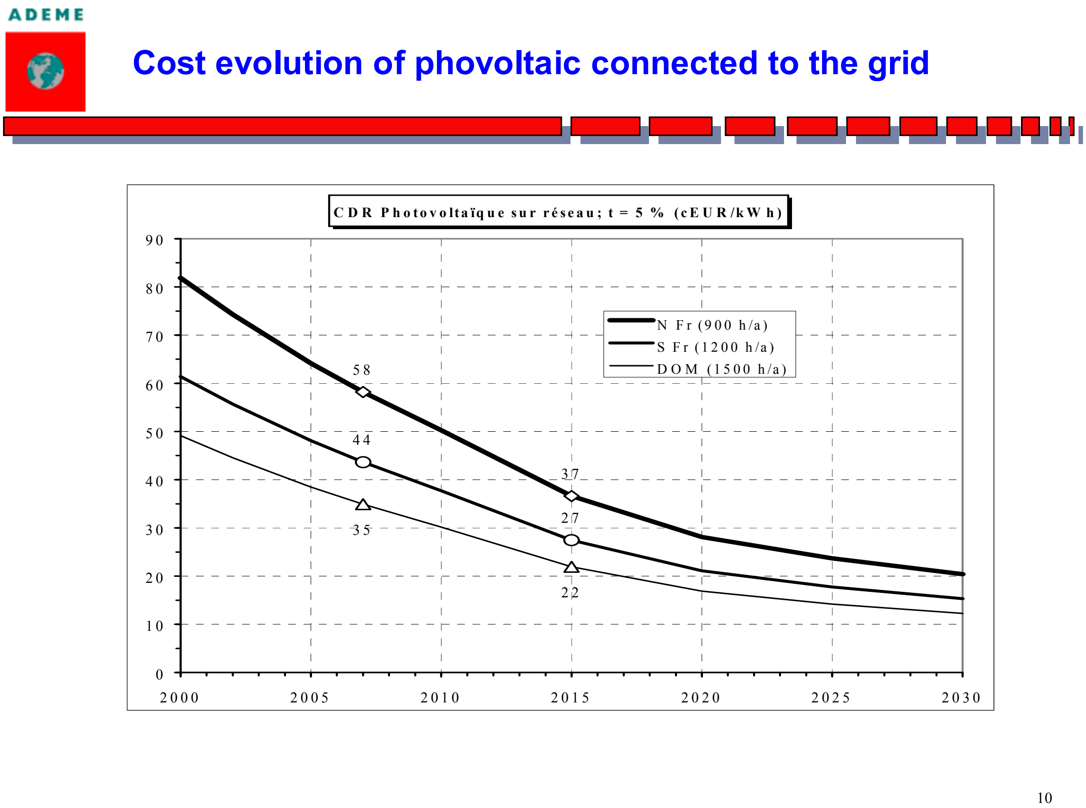


**Figure 8** - Cost evolution of photovoltaic connected to the grid

In order to compete with other electricity generation systems, scientific and technical breakthroughs need to happen (silicon production metallurgy process, thin layer of silicon, integration of modules in building materials such as glass, plastic films to cover walls and roofs). The objective is of 0.20 A$ per kWh around 2030.

In addition, all these costs & values correspond to industrialized country markets.

From previous comments, it is obvious that PV will become one of the major energy sources during this century because of its huge potential. It will modify considerably the electric systems design with the possibility to introduce power everywhere on the grid. That opens the door to a more decentralized scheme.

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[19] - i.e. a silicon panel investment 'alone' costs 1600 $ per kWp or 1000 Wp for a production on 1500 hours duration a year. The unit to express the capacity of a panel is the watt peak corresponding of the power delivered at optimal conditions of radiation.

On the graph, Tuvalu radiation conditions are corresponding to the lowest curve.

### IV.3.2 Solar Thermal

Solar thermal consists of using solar radiation directly to heat e.g. boiling water, cooking food.

- **Sanitary hot water production**

  - ***Collective use***

In Tuvalu, the only actual working application is to produce sanitary hot water for washing is in the new hospital. The 2 m² solar collector installation with a tank storing 300 litres of water is working well. Its production is equivalent to 0.3 toe if the water was to be heated by burning oil or LPG. It is manufactured by Solarhart, an Australian firm, which is the most important solar systems producer in the world.

The type of thermal solar technology we recommend implementing in Tuvalu is the simplest existing technology: solar collectors installed on a roof or on the ground next to water storage tanks or on the tank itself. Because of the hot climatic conditions it is unlikely that the system will have to be complemented with a boiler burning oil, biomass or LPG.

  - ***Individual use***

Arguments surrounding sanitary hot water supply to each house: On one hand, there is little need of sanitary hot water because of climate and tap water temperature. On the other hand, our attention has been drawn to the need for sanitary hot water by the hospital manager who has noticed an increase in the prevalence of skin diseases amongst children - possibly due to a poor standard of hygiene.

The temperature difference between the stored "cold" water and sanitary hot water in Tuvalu is small (around 10°C). To heat water to the required temperature is fairly simple and does not need sophisticated technology. One way, which is used in many countries to heat water for swimming pools (from 10 to 30°C), consists of a single rubber pipe arranged as a coil to form a plate laying down on the roof or on the ground. This coil is connected upstream with the tank storing cold water and downstream to the hot water tank (or pool). These simple solar collectors, often called "solar carpets", have no glass or metal parts. Their simplicity means a long life span and low maintenance costs.

- **Boiling water or cooking**

The second possible application for solar thermal is also related to health issues: Boiling water before drinking is essential to ensure public health standards are maintained. Solar thermal can provide clean drinking water whilst taking into account the present decentralized supply system.

The easiest way to boil water is with a solar cooker - a simple, cheap and robust technology. This technology, when used for cooking food, has not been very successful in other countries because it is slow, dependent on the sun and most effective around mid-day. However, boiling water only needs to be done once or twice a day without time constraints, so the technology should be successful for this type of application.

Assuming that drinking water need is 3 litres per person a day, that gives, at national level, 30 t/day which correspond to 363 toe per year – (including saving the actual consumption of 76 toe kerosene and 27 toe LPG per year).

## IV.4 OCEAN ENERGY RESOURCES

Other renewable technologies are promising, such as wave and tidal energy. They consist of the conversion of moving sea water into electricity and can be produced from regular sea currents, wave oscillation and tidal power station at the estuary of a river or offshore.

These technologies are still at a research stage. The UK is the most advanced country in this perspective. However, there is not yet any industrial scale application in the world. Clearly the increase in oil or gas prices and the obligation to decrease $CO_2$ emissions from electricity generation will stimulate research programs over the next decades.

Problems facing development are: technical factors such as the efficiency of conversion of water movement to electricity generation, intermittence management and the life time of components. Due to these factors the power generated is actually expensive.

It is clear that a country such as Tuvalu must have a real long term interest in the development of such technologies, but it is too early to setup a project. Consequently, a review of the progress of these technologies and their applicability to Tuvalu will be needed in around 5 years time.

# V ADOPTION OF RENEWABLE ENERGY ALTERNATIVES IN TUVALU

This Chapter presents recommendations and further steps required for RET implementation and to achieve PIGGAREP's aims.

## V.1 GENERAL COMMENTS ON BARRIERS BLOCKING RE DEVELOPMENTS

There are now clear policies and plans to guide renewable energy development in Tuvalu (Tuvalu's own energy policy; PIGGAREP; PICCAP - Pacific Islands Climate Change Assistance Programme; PIEPSAP - Pacific Islands Energy Policies and Strategic Action Planning; PIREP- Pacific Islands Renewable Energy Project), although commitment to implement this policy has yet to be demonstrated. This is partially due to the existence of a number of barriers to renewable energy technology which can be broken down with effective strategic planning, training, technology selection and implementation.

***Barriers to implementing modern renewable energy applications in Tuvalu and strategies to overcome these barriers:***

| Barrier | Strategy |
|---|---|
| Lack of appropriate technology selection – mainly due to a reliance on outside aid which has dictated technology options. | GoT to draw up a protocol for outside aid for energy applications which takes into account PIGGAREP, PICCAP, PIREP & PIEPSAP recommendations. In the past the Pacific region seems to have been used as a testing ground for new technologies. GoT need to ensure that only appropriate & established RET's are implemented in Tuvalu. |
| Lack of technical expertise and institutional structure to plan, manage and maintain RE programmes. Lack of printed end-user instructions in Tuvaluan. | Training is the key to this barrier. Any RE intervention must have an associated training programme. In addition, Tuvalu's existing facilities (USP, schools, TMTI workshop) can be integrated to provide ongoing training & back-up. Any RE intervention must also have an agreed management & economic plan, possibly with the set-up of a service providing organisation, as part of any project exit strategy. |
| Ineffective long-term management. | To be effective training must be given in organisational structure & accounting. A service provider needs to be set-up for any energy services. Dedicated specialist units with technical & financial expertise would be most beneficial. |
| Misguided institutional mechanisms – including badly targeted subsidies and legislation which limits consumer choice (e.g. 2003 copra subsidy & Funafuti electricity regulation – all electricity use has to be via connection to TEC; diesel fuel is duty and tax free for power generation; subsidised TEC tariffs. | Any legislation should at least provide a level playing field for all sources of energy. RET's reduce pollution & GHG emissions firstly by replacing polluting fossil fuels & secondly as they are zero net carbon emitters when used sustainably. Using bioenergy would revitalise Tuvalu's copra industry and help reach PIEPSAP commitments. It therefore makes sense for Tuvalu to introduce institutional mechanisms which favour renewables. |
| Lack of successful demonstration projects. | Solar has been successfully demonstrated in Tuvalu. Other RET's such as biogas and biodiesel production could be demonstrated using TMTI (Amatuku) as a model. Training & awareness programmes could also be based at Amatuku. |
| Requirement for complex project proposals by financing institutions and lack of awareness of available funding. | Additional training and support for TANGO and engaging the skills of international funding institutions and NGO's to help prepare funding requests. An internet based network/forum to provide further information on available funding. A business co-ordinator/ business development centre to appropriate funds and projects. |

| | |
|---|---|
| Lack of coordination between regional & local institutions & GoT departments leading to duplication of planning & research studies. | Develop a region-wide internet based network/forum, with an emphasis on topics directly affecting Tuvalu to ensure all stakeholders can send and receive appropriate information. |
| Lack of awareness of available alternatives. | SOPAC/ICEPT Biomass Energy Programme (2003) raised awareness of bioenergy alternatives for GoT & other stakeholders. In addition, Alofa Tuvalu (2005) raised awareness amongst various women's groups in Funafuti & Vaitupu. Similar programmes need to be run and expanded to cover all RET's and all areas of Tuvalu. |
| Lack of awareness of energy efficiency issues. | Run an awareness campaign (radio, internet, posters, etc) at GoT and general public level. |
| Problems posed by small and dispersed energy markets. | Because of Tuvalu's geographical isolation this issue will always remain a problem. However, if the region acts together (e.g. through various regional organisations & plans), then some of the associated problems will be overcome. |

From the Alofa Tuvalu fieldwork (2005) it was evident that energy efficiency is not yet a policy priority. As a result there are many opportunities for energy savings in most industrial, economic & domestic sector activities that are often ignored and are still not dealt with in the new energy policy (mainly because the low prices of oil over the last few years and because of lack of awareness).

There also appears to be a lack of confidence in various technologies (biomass and wind in particular) as well as a lack of local financial commitment and support for renewable energy due largely to economic constraints – both institutional (e.g. solar for the new GoT building), and low household income on the other side of the scale. This lack of finance means continued reliance on outside agencies to pay for installation costs of RET's.

Additionally, women, who play a central role in energy use, have largely been ignored. They must play a full part in energy policy development and implementation.

However, it is worth Tuvalu overcoming the above barriers and challenges and taking positive steps to favour the adoption of RETs since:

- RET's reduce the amount of pollution and GHG's entering the atmosphere firstly by replacing polluting fossil fuels and secondly as they are zero net carbon emitters when used sustainably.
- By using RET's Tuvalu will strengthen its case in climate change negotiations and provide an opportunity to do something proactive to demonstrate that Tuvalu is taking an active role to abate GHG production.
- Provide fuel security and reduce Tuvalu's dependence on imported oil, hence reduce the amount of money leaving Tuvalu, thus strengthening the general economy and balance-of-trade position.
- Protect Tuvalu's energy supply from the whims of the international market.
- Using specific bioenergy technologies such as biogas digestion can help reduce pollution, run-off and contamination from organic waste, including human and animal sewage, therefore preventing land, sea, and groundwater contamination. Additionally, the slurry produced from the digestion process can be used to improve soil quality and fertility, or can replace soil in areas where soil is heavily contaminated, such as salt contaminated soil from sea water flooding. Where land and soil is scarce, it can be used to support a program of "family gardens", which will help decrease the amount of

household income spent on food – an expensive imported commodity. Additionally, biogas can be used as a fuel for cooking or to run a diesel generator.

- Using bioenergy on Tuvalu's outer islands to provide a reliable electricity supply will support cottage industries, increase family income, provide new employment opportunities and improve quality of life thus reducing migration to Funafuti.

- The re-introduction of copra production for biodiesel will have many multiplier effects: provide income to outer islands; reduce oil imports; increase biodiversity by replacing old coconut trees and re-foresting degraded areas; provide timber as old trees are cut and replaced; provide a carbon neutral energy source; provide much needed jobs in rural areas. The biodiesel produced can have a number of end uses such as transport fuel (sea and land transport) and electricity generation (outer islands and Funafuti).

- At current population and food import levels there does not appear to be any competition between land use for food and fuel. In fact, an integrated bioenergy and agricultural extension plan would increase the amount of food produced in Tuvalu whilst decreasing the amount of waste since compost would be produced as a consequence of waste processing.

## V.2 Reducing Energy Requirements: Energy Efficiency

It should be stated that when considering any "rational use of energy" one of the first things to look at is improvements in energy efficiency. Energy efficiency reduces the amount of primary energy required to achieve the same service provision. There is currently no legislation in Tuvalu relating to energy efficiency - for building regulations, vehicle efficiency & emissions or codes of best practice for saving energy. The situation could be helped by simple solutions such as:

- ***To setup a standard code for imported equipment***

That means to import only energy efficient electrical appliances (e.g. light bulbs, ridges, etc.). The slightly higher initial cost of energy efficient equipment, construction components and domestic appliances actually represents a saving over the life of the equipment/appliance as running costs are much lower.

- ***To adopt a building code for new construction***

Additional initial costs associated with the construction of energy efficient buildings are actually a saving when compared with the avoided costs of cooling. It is always more expensive to counterbalance a bad choice of initial building design by later renovation works.

This building code has to specify the ways of protecting buildings from direct sun exposure, especially south facing glass surface, which can often be accomplished by something as simple and as inexpensive as well-designed planting of shade trees. It is always economically sound to diminish the need for cooling. This kind of progress towards energy efficiency will have a positive impact on electricity production because peak load will be decreased in the middle of the day when cooling systems are usually operating at maximum.

Many countries with climate conditions equivalent to Tuvalu have introduced building codes and can be used by the GoT as a basis for preparation of their own legislation.

The first step will be to design and implement a building code for public buildings. Experience from other countries shows that design requirements should be increasing slowly, step by step, every five years to give time for construction professionals to adapt and to prevent over-costs. A training program for Tuvaluan construction professionals can easily be setup and financed through an international partnership.

- ***Deciding standards for imported vehicles*** to prevent a huge increase in oil consumption for road transportation. More cars on Funafuti will create a major strain on future oil imports & impact on electricity provision as well as on the amount of diesel available for sea transport to the outer islands. Car ownership in Tuvalu does not take into account the countries geographic reality. This issue calls for immediate and appropriate regulatory action from the GoT: The impact on the national economy of oversized vehicles is real. A car with a maximum speed of 220 km/h consumes twice as much fuel as a car with one of 140 km/h in the daily conditions of traffic in Tuvalu. The first step is to organise a debate about this major policy of the country including professionals and NGO's. The more we let time pass, the more difficult it will be to decide. In addition, the new oil crisis makes the debate about which type of vehicles are best adapted to Tuvalu's roads, climate and geography, an urgent priority.

Some steps could be taken to prevent vehicle use becoming a larger problem for Tuvalu:

- Introducing vehicle emissions testing;
- Create regulations defining maximum speed (engine size) on all imported vehicles.
- Impose a significant taxation on those vehicles that are above 1300 CC (with an exception for professional justified uses) and limit the CC of all imported motorbikes to 125cc. The conditions in Tuvalu suggest that a vehicle does not need to run faster than 40 km/h with a practical average speed of around 30 km/h. Introduce a vehicle tax for vehicles which exceed the engine sizes detailed in the legislation.
- Create a vehicle rental service with the help of existing taxis and buses, with the communities, for occasional needs and use.
- Form partnerships with one or several electric car builders for supply of cars, pickups and motorbikes; considering Tuvalu's interest in saving oil and currency, it seems that Tuvalu may have an interest in using an electric fleet of vehicles, which would be particularly beneficial if the share of electricity coming from renewable sources increases.
- The increase of road vehicles will have severe environmental impacts: already, there is no local disposal site for batteries, tyres, and old vehicles. The landfill is currently unusable, much too small and not designed for hazardous wastes associated with vehicle disposal. A negotiation should be held with TCS and other importers to organise a return freight, using empty containers, with a regional solution to old vehicle disposal in Suva or another surrounding country.
- Consider a free community push-bike scheme. These would be brightly colored for easy identification and equipped with baskets to carry groceries, small children, etc. with pick-up and dropoff locations at major public gathering places, such as the airport/govt. building, the wharf and the large FUSI market. Many large cities in Europe have or are developing such programmes.

In addition, all of the above measures are decreasing the purchase price and running costs of the vehicles. Another plus for Tuvalu's economy!

- ***To adopt/enforce a law about waste policy***

This has to include a scheme for recycling domestic and commercial waste (glass, metals, plastics, organic wastes– a deposit system on bottles & cans may be as effective in Tuvalu as it has been in Kiribati), to organise a disposal site protecting the soil and the lagoon and organising the export of toxic wastes to appropriate facilities. GHG emission, in particular methane, could be substantially reduced by limiting the amount of organic rubbish going for waste disposal. This could be achieved by implementing RET's such as biogas digestion and gasification that use these materials as feedstock for electricity production.

## V.3 Adoption of Biomass Energy policy

There are many opportunities available for successful sustainable adoption of RET's which could be developed and which would in turn help to solve the range of the issues highlighted, if carefully implemented, with particular reference to reducing imported oil, increasing household income via reviving the copra industry, and reducing health & environmental risks by using organic waste for energy.

### *V.3.1 Charcoal Stoves*

Alofa Tuvalu survey results (2005) indicated that the use of charcoal would be even higher if there was a more regular supply. In the majority of cases the men (young & old) of the household were responsible for charcoal making but did not always make it regularly. Therefore, there is a small business/ income generating opportunity for someone within the community to make charcoal from coconut shells and sell it to users on a regular basis – possibly a women's group. Charcoal stoves are generally of simple design & are made from concrete – there may also be an opportunity for at least one person in a community to make, sell and promote the use of charcoal stoves.

| Charcoal stove of the type commonly used in Tuvalu | Kerosene stove of the type commonly used in Tuvalu |
|---|---|
|  |  |

**Figure 9** - (A) Charcoal stove of the type commonly used in Tuvalu,
(B) Kerosene stove of the type commonly used in Tuvalu

Around 335 toe of currently unused coconut shells are available in Tuvalu – this would be enough to provide around 200 toe charcoal for domestic use.

### V.3.2 Biodiesel Production

Biodiesel can be produced from potentially all oil producing crops. In Tuvalu, coconut is the dominant oil producing crop - recovered cooking oils and animal fats also represent a potential resource for biodiesel production, but have not been considered by this study. Attention has been paid to the co-products of biodiesel production. These include glycerine, which is used in the soap making and the cosmetics industry, and a protein rich press-cake (copra cake) which is used for animal feed.

#### V.3.2.1. Conversion Technologies include:

Simple mature technologies including pressing, filtering and esterification are used. At the small scale (<1 t seed per hour) screw presses are used. At larger scales, high and low temperature presses with or without solvent extraction in hexane are used.

- Pressing, filtration and batch esterification.
- Pressing & continuous high pressure esterification
- Pressing, boiling, centrifugation, esterification & filtration.

The production of Vegetable Methyl Ester (VME) or "biodiesel" (including Coconut Methyl Ester - CME) requires the extraction of the oils from the seeds of the crop. In the case of CME, oil is extracted by pressing the copra. The coconut oil is then filtered / purified, and may be boiled to remove water followed by an esterification step using an alcohol (methanol or ethanol) in the presence of a catalyst and heat. This is a simple and efficient process. Under certain circumstances it is also possible to use Straight Vegetable Oil (SVO) (or in the case of coconut oil – CNO) as a transport fuel and to power modified diesel engines.

The historical use of SVO as a fuel was rapidly superceded by petroleum-derived mineral diesel as a result of both economic and technical factors. Modern diesel engines are manufactured to high engineering tolerances and therefore cannot cope with gums that can build up during the combustion of SVO. CNO is also prone to solidification at temperatures below 20 to 22ºC requiring modified fuel storage and delivery systems – but this is unlikely to be a problem in Tuvalu!

In order to overcome these issues, filtration/purification and esterification processes are used as the resulting CME (biodiesel) has similar physical properties to mineral diesel but superior combustion qualities as it contains 11% oxygen, better lubricant properties than modern ultra low sulphur diesel, increased efficiency and a dramatic reduction in particulate emissions (as it burns more effectively), it has nil sulphur content and, unlike mineral diesel, contains no carcinogenic compounds, and it does not result in gum and carbon deposit problems - so injectors are less likely to become clogged with carbon deposits(Greenergy, 2002; Woods & Baun 2003; Weingart & Manapol, 2005). The use of CME should not require any engine modification but in older cars rubber components in the fuel delivery systems need to be replaced with resistant alternatives e.g. neoprene. CME can be used in blends from 1 to 100% with mineral diesel (Woods & Baun 2003).

Esterification takes place at about 50°C, usually by the addition of alcohol (methanol or less commonly ethanol) to the SVO/CNO. The outputs of this process are the esters (biodiesel) and glycerine. Approximately 100kg of glycerine is produced per 1000kg of esters. Sodium or potassium hydroxides are used as catalysts to speed up the esterification process. The most common technology uses batch processing with commercial plants operating at scales of 500 to 10,000 t/yr. More recent technologies include the Henkel Trans-esterification system, which relies on two tube reactors followed by settling tanks, operating at 4 to 5 bar pressure and 70 to 80 °C.

The basic chemical process involved in the production of CME (coconut oil biodiesel) is shown below and highlights the role of the alcohol (in this case methanol) and the associated production of glycerine in the process.

$$\underset{\text{(Triglyceride)}}{C_3H_5(OOCR)_3} + \underset{\text{(Methanol)}}{3CH_3OH} \xrightarrow{\textit{Catalyst*}} \underset{\text{(Methyl Ester)}}{3RCOOCH_3} + \underset{\text{(Glycerine)}}{C_3H_5(OH)_3}$$

Note: * Catalysts used include Sodium Hydroxide (NaOH) and Potassium Hydroxide (KOH).
'R' represents long chain esters.

The relatively new 'continuous deglycerolisation' (CD Process) technology, runs at ambient pressure and temperatures between 65 and 70 °C and uses a centrifugal glycerine separation system. This is the system running at Vanuatu Sea Transport – producing on average 2,000 litres of coconut oil biodiesel (CME) per week. This may be the most appropriate technology for Tuvalu.

#### *V.3.2.2 Biodiesel Production in Tuvalu*

Tables 2 & 3 indicate that the biomass energy resource is not a constraint on CME production. Tuvalu could produce around 550 toe CME (700,000 litres) every year (annually replacing approximately 50% of current mineral diesel oil use on the inter-island boats) and 70 toe glycerine for soap & cosmetics production.

The main copra production is in Vaitupu (Tables 4 & 5). While travelling in the outer islands, Alofa Tuvalu held 3 meetings concerning copra production and its future development in Vaitupu. Items under discussion included: the collapse of the copra market; lack of income for farmers from coconut and copra production; biodiesel production from coconuts; the use of biogas digesters as a means of producing domestic cooking fuel and much needed compost as well as providing sanitary housing for pigs. All attendees at the meeting were aware of the environmental benefits of biomass energy and all were very much in favour of exploring the possibilities of revitalising the copra industry via biodiesel production.

##### TUVALU'S COPRA MARKET COLLAPSE

The copra market collapsed[20] in 2003 and there has been no copra trade in Tuvalu since then. This has meant that copra producers have no source of income from copra production. Part of the problem has been the high price demanded by Tuvalu's copra producers (A$1 per kg copra c.f. a world market price of 0.25-0.35A$) in 2003 & 2004. The meeting revealed that this was partly due to election promises made by politicians to continue subsidising the copra market, even though the ADB had already advised against this subsidy.

[20] For further details please refer to Biomass Energy Potential in Tuvalu - Sarah L. Hemstock (Alofa Tuvalu, 2005)

Another part of the problem was the choice of market. The GoT was paying money to export the copra to Fiji. Exporting from Tuvalu - because of isolation, distances, and small volume produced – will always be uneconomical.

Three recommendations can be drawn from the collapse of the copra market:

- To develop a local market for copra oil to substitute for imported diesel. This approach would avoid the cost of sea transportation for export of copra and importation of diesel…
- To choose a market directly related to the main energy needs of Tuvalu: electricity supply and transportation.
- To identify sustainable economic conditions and to create jobs. It is also crucial to choose a technology which can result in better conditions of working conditions compared to the handwork way in the past.

### *AGREEMENTS OBTAINED FROM COPRA GROWERS DURING THE 2005 FIELD ASSIGNMENT*

It was apparent that the lack of income from copra is now having a serious negative effect on many household incomes in Vaitupu.

- It was agreed that producing copra for biodiesel offered a promising solution. The existing Kaupule coconut oil production facility only provided a small income for 5 people at the most. It was decided that the best way forward was to hold 2 meetings with farmers who used to make copra and discuss the issues with them as well as get an idea of a price per kg of copra that they were prepared to accept.

- At each of the broader community meetings it was agreed to give a clear explanation of the options available and the benefits and drawbacks. The Kaupule Secretary and the Alofa Tuvalu Representative would present the technologies to the community meetings. It was hoped that each community meeting would give a clear mandate of acceptance or rejection of the options available.

- A positive mandate was obtained from the community meetings and it was agreed that the MP for Vaitupu would take the mandate forward to Parliament to express Vaitupu's interests in biodiesel and biogas.

- There was much discussion about the price of copra and the size of the copra market for biodiesel production. It was agreed that if a large quantity of copra was produced, then total payments would be competitive and a price of 0.35 A$/kg was accepted.

- At the second community meeting the mandate was very positive in favour of exploring biodiesel production as a means of income for copra producers. Much discussion took place around the price of copra. Since there had been no copra production and hence no income from copra for the past 2 years, it was agreed that copra should be sold for the world market price (currently 0.25-0.35 A$/kg).

However, many community members were concerned about training issues as one of the two coconut oil mills on Vaitupu had broken down and no one knew how to fix it (it was currently being repaired by the Kaupule, but had been out of action for at least a year). The community stressed that any project should involve a strong technical training and maintenance element.

### *V.3.2.3 Biodiesel Recommendations:*

The Alofa Tuvalu (2005) survey indicated an annual resource potential of 1,653 tonnes of copra. However, historical data for copra production in Tuvalu indicates that the highest ever production was in 1979 when 808 t was harvested – this would provide about 28% (approx. 306 toe) of the fuel used by the inter-island ships. In 2001 as little as 32 t was harvested. Around 250 t/yr seems to be the most common production value for the whole of Tuvalu. 205 t copra would provide about 9 % (approx. 95 toe) of the fuel used by the inter-island ships. It is apparent that annual coconut yield has little or no bearing on the amount of copra produced per year (see Tables 2 & 3 – coconut production in Tuvalu).

Copra production is not constrained by a lack of coconuts. It would appear that the amount of copra produced per year is more dependent on other factors such as remittances from overseas (e.g. payment from seamen) and other sources of disposable income available to copra producers.

Long term contracts for copra production, payment for production and coconut woodland rehabilitation and replanting should be negotiated with copra producers and land owners. Long term contracts between biomass growers (farmers) and energy companies ensure a consistent supply of fuel for bio-energy plants in the UK, Europe, the US & Brazil. From the historical inconsistencies in copra production in Tuvalu it would appear that a contractual approach may be the best way of ensuring a consistent supply of copra.

The contracts should include:

- Guaranteed copra production quotas;
- Guaranteed fair payment for production;
- Replanting subsidy and land rehabilitation subsidy;
- Agreed incentives and disincentives;
- Guaranteed training in operation and maintenance.

A large scale coconut oil production facility was implemented in Kiribati in 2002/2003 at a cost of A$ 4,000,000. A smaller biodiesel plant on Vaitupu may cost in the region of A$ 1,000,000; with a view to expanding this initiative to cover all outer islands. For Tuvalu, technology selection will depend on the scale of the production facility and the requirements for CNO (to be used in modified diesel electricity generators – CNO use in unmodified marine engines will require further investigation) or CME (to be used for land and sea transportation). CME mini-refineries with a production capability of around 200 litres per day can cost as little as AS$ 150,000 – including basic oil extraction equipment (World Bank, 2004). This scale may be most appropriate to Tuvalu's needs.

If a larger scale biodiesel initiative were to be implemented it should be done on a more formal basis than past Tuvalu Copra Trading Corporation activities and a replanting scheme should be developed and implemented to insure future productivity.

To mix a biodiesel (VME/CME/CNO) with mineral diesel is a common practice in the world. However, to avoid any unlikely damage to the inter island boat engines, it is wise to test various mixes. Tests could be done in collaboration with the French CIRAD specialists, who have been working on such production in France, New Caledonia and other territories. The identified mixture could be used in the inter island boat marine engines. Using marine engines could be most advantageous because they are slow and efficient engines able to operate in variable conditions.

Advantages of using biodiesel for sea transportation include :

- Local refilling of the inter-island ships during the island to island trips will have extra advantages: to diminish the need to make the trips to Suva to refill and to reduce the quantity of fuel carried.
- The introduction of biodiesel will decrease the emissions of sulphur dioxide.
- To decrease dependency on imported oil for essential sea transportation for people and goods would be a common goal for all the countries of the South Pacific. It would be useful for these countries to engage in a joint research program and to develop the technical aspects to ensure such development. The Tuvaluan GoT can submit this proposal into regional programs for funding.

### V.3.3 Biogas from pig waste

Biogas is produced by the anaerobic fermentation of organic material. Production systems are relatively simple and can operate at small and large scales practically anywhere, with the gas produced being as versatile as natural gas. This is a very significant technology option for Tuvalu since anaerobic digestion can make a significant contribution to disposal of domestic and agricultural wastes and thereby alleviate the severe public health and water pollution problems that they can cause. The remaining sludge can then be used as a fertiliser (providing there is no polluting contamination) and actually performs better than the original manure since nitrogen is retained in a more useful form, weed seeds are destroyed, and odours reduced. In addition, it would reduce the amount of household income spent on cooking fuel, provide much needed compost for family gardens (sea water encroachment has contaminated traditional taro and pulaka pits) and thereby provide additional food security, dispose of pig waste which is currently swilled into the lagoons, and may provide additional household income from pig rearing and sale of gas.

#### V.3.3.1 A COMMUNITY BASED ACTIVITY AND BUILDING CAPACITY

Failed projects show that communities must be involved in the decision making and project planning process from the outset (Woods, *et al,* 2005). Establishing a community need for energy services is the first step in the planning process. This approach should give beneficiaries a sense of ownership of the project and will help ensure good ongoing maintenance and that any intervention and exit strategy is socially, environmentally, and economically sustainable. In addition, the resources available must be the initial starting point for any community based bio-energy project.

Women's groups were approached initially since women are the main users of biogas as a domestic fuel and any activity concerning the implementation of this technology should involve them directly in order to ensure sustainability. Women were to be involved from the outset. A series of 11 meetings with women's groups were held to discuss biogas technology and implementation. At a meeting at the Vaitupu Kaupule, the Alofa Tuvalu representative stressed the importance of involving women in the planning and decision making process as they were the main users of the fuel. It was agreed to organise a meeting in conjunction with "Women's Week" which would ensure a large number of participants.

The first women's meeting was held in Vaitupu (17/08/05). Over 100 women were in attendance. They decided unanimously that they wanted to explore the possibilities of implementing biogas on Vaitupu and it was decided that a planning committee of 21 women would take the idea forward. Over the next few days they developed an implementation strategy involving a series of 15 family sized (6 $m^3$) digesters. They obtained permission to use land to site the family digesters & pig pens and also planned a larger community based digester for each of the 2 villages on Vaitupu, although no agreement was reached as to where to site the community plants. The women also decided that the promotion of family gardens would run alongside the implementation of the family sized digesters.

Building on the success in Vaitupu a further series of 8 other women's group meetings were held in Funafuti with each of the outer islands Women's Associations and with a women's gardening association.

**Figure 10**-women's community meeting in Funafuti

Alofa Tuvalu was promoting Family Gardens & Composting as an activity throughout Tuvalu and brought many types of organic seeds (tomato, lettuce, basil, melon, marrow, chilli pepper, long beans, watermelon etc..) to fulfil a 2004 request from Seluka Seluka (Head of Sustainable Agriculture in Tuvalu) for trialling at the Agricultural Station and distribution to Vaitupu households. Around 15 kg of organic seeds donated by two French associations were distributed by Alofa Tuvalu to all women attending meetings as well as interested government personnel and anyone who wished to try.

The basic format for each meeting was:

- To describe the background of Alofa Tuvalu & the "Small is Beautiful" project.
- To make clear links between climate change, carbon emissions and energy use.
- To point out benefits of family gardens (food security, improved income, reduce waste by compost making, reduce reliance on imported foods, etc.).

- To give instructions on how to set up a family garden (ground preparation, where to buy compost, planting seeds, watering, pollination, collecting & storing seeds, organic fertiliser & compost techniques, etc.).
- To supply seeds to the women (tomato, lettuce, basil, melon, marrow, chilli pepper etc).
- To describe biogas technology and types of implementation – examples of community biogas plants in India and a pig farm in Suva, Fiji. Discussing added benefits of a reliable gas supply and compost production. Providing women with information about the technology so that they can formulate an initial project strategy.

These are beneficial activities since they:

- Promote soil production & improvement;
- Work well in conjunction with biogas digester projects;
- Reduce the amount of waste going to landfill;
- Improve food security;
- Increase household income by reducing the amount spent on imported food and surplus production can be sold to generate further income;
- Provide a wide range of healthy, fresh, nutritious products which improve diet.

In general, the attendees were extremely positive about biogas and family gardens. They requested help with compost making and marketing surplus home garden produce. When asked about their feelings about national, community or family digesters, the majority of the groups chose family or community based implementation.

Nui Island Women's Association was the most enthusiastic of the groups approached in Funafuti, asking questions such as "what can we feed the pigs to get them to produce more gas?" They were also very interested in starting their own family gardens and picked up on the idea of installing biogas very quickly and thought that it would be beneficial to Nui as people keep many pigs and have land to site the digesters. However, on Funafuti, since most of the Nui population do not own land on the main island, they came up with the idea of a national system – along the lines of the Suva example (see Annex 1 below) with more pig housing than the Tuvalu Model Piggery (TMP). They proposed a large piggery (150 – 200 pigs) and digester as a Women's Community Project on land donated to the Women's Community on Nui. It has to be noted though that none of the Nui attendees kept their pigs at TMP because it was built on land belonging to Funafuti people. The women advised that issues concerning land ownership would have to be dealt with at the beginning of any project.

Apart from the size of the digesters, the Nui community meeting reflects much of what the other islands women decided, i.e. :

- Women should be trained in all aspects of digester running & maintenance as well as husbandry;
- Biogas should be used as cooking gas, rather than electricity production, since the supply of bottled gas is erratic and expensive as it has to be imported from Fiji.
- Women will take turns to tend their pigs and collect coconuts for the pigs and labour will be free;

- The Women's Community will own a proportion of the pigs which will be reared and sold to the Tuvalu Cooperative Society shop to generate revenue;
- The use of the pig pens should be free to the women looking after the set up and a hire charge for those who do not;
- Cheap gas for members of the Women's Community & a higher charge for non-members;
- Cheap compost for members of the Women's Community & a higher charge for non-members.
- Set up a vegetable garden in combination with the digester where vegetables would be cheaper for members of the Women's Community & more expensive for non-members.

### *V.3.3.2 Biogas possible implementation*

Small-scale digesters are appropriate for small and medium-sized rural farms. Typical fixed-dome small-scale digester sizes range from 4-5 $m^3$ total capacity design for small single-family farms, to 75-100 $m^3$ total capacity designs. A digester having a capacity of 100 $m^3$ can handle about 1800 kg of manure per day and would be suitable for a farm with about 30 cows or 150 pigs. This scale would be most suited to Tuvalu Model Piggery – the community owned piggery on Funafuti were people rent stalls to house their pigs.

Basic digester systems will produce around 0.5 $m^3$ of biogas per $m^3$ of digester volume. For a family of 6, digester systems of 4-6 $m^3$ can meet daily biogas requirements (about 2.9 $m^3$ of gas) for all residential and agricultural uses). Efficient digesters with gas recovery systems may reduce methane emissions up to 70%, with larger reductions achievable for longer retention times. This technology can make small and medium-sized households more self-sufficient and reduces GHG emissions [21].

The following tables were drawn using a conservative collection efficiency of 60% of total dung produced and conservative conversion efficiencies from family based 6 $m^3$ digesters (15 pigs per digester).

| Total number of pigs on Funafuti | Total annual production of pig manure | Total annual production of energy from pig manure | Total amount of manure available annually for use in biogas digester* | Total amount of energy available annually for use in biogas digester* |
|---|---|---|---|---|
| head | $t.yr^{-1}$ | $GJ.yr^{-1}$ | $t.yr^{-1}$ | $GJ.yr^{-1}$ |
| 3834 | 1119 | 10,075 (240 toe) | 672 | 6045 (144 toe) |

*Assumes 60% collection efficiency as some waste is used for compost and some will be difficult to collect (Alofa Tuvalu, 2005). –

**Table 8-** Energy available for biogas digestion from pig waste in Funafuti

For Tuvalu a total of 1,578 $m^3$ of gas could be produced per day – providing 13,236 $GJ.yr^{-1}$ (315 toe). This is more than enough to provide the cooking gas (and possibly electricity for lighting) for 526 households across Tuvalu. Additional benefits include compost production, cleaner pig pens and the removal of a smelly hazardous waste.

[21] - Methane is a greenhouse gas with a potential to disturb the climate 20 times greater than carbon dioxide.

| Total number of pigs on Vaitupu | Total annual production of pig manure | Total annual production of energy from pig manure | Total amount of manure available annually for use in biogas digester* | Total amount of energy available annually for use in biogas digester* |
|---|---|---|---|---|
| head | $t.yr^{-1}$ | $GJ.yr^{-1}$ | $t.yr^{-1}$ | $GJ.yr^{-1}$ |
| 2267 | 662 | 5957 (142 toe) | 397 | 3574 (85 toe) |

*Assumes 60% collection efficiency as some waste is used for compost and some will be difficult to collect (Alofa Tuvalu, 2005).

**Table 9 -** Energy available for biogas digestion from pig waste in Vaitupu

For Vaitupu, a total of 263 $m^3$ of gas could be produced per day – providing 2433 $GJ.yr^{-1}$ (58 toe). This is equivalent to total kerosene use for cooking in all households in Vaitupu. It is more than enough to provide the cooking gas (and possibly electricity for lighting) for 91 households.

| Total number of pigs on remaining outer islands | Total annual production of pig manure | Total annual production of energy from pig manure | Total amount of manure available annually for use in biogas digester* | Total amount of energy available annually for use in biogas digester* |
|---|---|---|---|---|
| *head* | $t.yr^{-1}$ | $GJ.yr^{-1}$ | $t.yr^{-1}$ | $GJ.yr^{-1}$ |
| 6228 | 1819 | 16,367 (390 toe) | 1091 | 9,820 (234 toe) |

*Assumes 60% collection efficiency as some waste is used for compost and some will be difficult to collect.**Table 10 -** Energy available for biogas digestion from pig waste in Tuvalu remaining Outer Islands

In Funafuti, a total of 491 $m^3$ of gas could be produced per day – providing 4116 $GJ.yr^{-1}$ (98 toe). This is more than enough to provide the cooking gas (and possibly electricity for lighting) for 153 Funafuti households.

### *V.3.3.3 Project feasibility and economical viability based on Colo-i-Suva Pig Farm, Fiji.*

The Fiji project was deemed both technically viable and appropriate for Tuvalu and assessment revealed that there was more than sufficient dung resource to supply the proposed digesters in Tuvalu. Costs associated with a 6 $m^3$ digester for bio-gas generation equipment, drainage for pig pens and labour would not be higher than 5000 Aus $ including material and labour – construction costs for "designed-for-purpose" pig pens may be higher and, for Tuvalu, transportation costs would have to be taken into account. These costs can be written-off over the life-span of a biogas plant which is assumed to be 25 years.

| | | | |
|---|---|---|---|
| ***Annual Savings*** | A$ 492-832 | ***Annual Costs*** | A$ 0 - 120 |
| Fuel wood (7 kg per day @ 0.05 per kg) | A$127.75 | | |
| Kerosene/LPG/electricity | A$364-600 | Maintenance costs of digester materials are between | A$ 50 - 120 /yr |
| Fertilizer (slurry) | A$ 0-105 | | |

Lifetime of equipment: 25 years

| | |
|---|---|
| *Pay back time* : | 6 to 11 years |
| *Savings over equipment lifetime:* | A$ 4,540 to 14,650 |

(Not including income generating activities such as sale of gas, pigs and vegetables, or sale of compost)

### *Anticipated implementation problems*

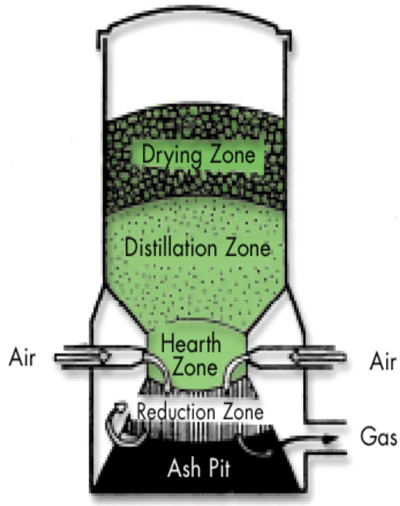
- Occasionally, after periods of severe rainfall, the Fiji digester filled with too much water & had to be drained. The farmer did not service the pipes running from the pig-pens to the digester so they occasionally became blocked.
- Problems such as rain-water flooding of the digester can be easily avoided by correct site preparation when the digester is built; other technical problems with the project arose because of improper maintenance. Training and an agreed maintenance schedule could overcome these problems (see Amatuku model below).
- There is currently no example of biogas technology being implemented on a coral atoll. Construction costs may be higher than anticipated due to difficulties of a high water table and sea water flooding.
- Land tenure issues are complicated in Tuvalu so any land use issues must be worked through before construction commences.
- For this type of project there is an important role for innovative financing to enable consumers to spread the high initial cost of energy conversion technology over the life of the equipment (cost analysis above). This is particularly true for poor farmers running smaller scale digesters who by definition have little to offer as collateral and who are unfamiliar with formal credit systems.

### *V.3.4 Gasification of unused coconut husks and shells*

Gas turbines for electricity generation can be fuelled by gas produced from biomass converted by thermochemical decomposition in an atmosphere that has a restricted supply of air. Gas turbines have lower unit capital costs than steam turbines, and can be considerably more efficient. In the simplest open-cycle gas turbine, the hot exhaust of the turbine is discharged directly to the atmosphere. Alternatively, it can be used to produce steam in a heat recovery steam generator. The steam can then be used for heating in a cogeneration system. In addition to utilisation of biomass fuels in relatively small power plants designed only for these feedstocks, biomass can also be co-utilised with fossil fuels in large scale power plants.

Feedstock Storage, Hopper & Gasifier.

Ford Engine Block (electricity generator – situated behind the gasifier)




Schematic of Downdraft Gasifier.

**Figure 11** Gasification plant Onasewa school in Vanuatu (50 kW)

The unused husks and shells (which total 482 toe across all Tuvalu) would be ideal fuel for a series of gasifiers on each island for electricity generation for the grid. Vaitupu has 176 toe of unused husks & shells, Funafuti 117 toe & the remaining outer islands have 188 toe. However, at the moment, the majority of this organic waste is tipped on sites set aside by the Kaupule and on illegal sites (in Funafuti). Less than 20% is composted as only 6-19 % of respondents had family vegetable gardens, 6% in Vaitupu and 19% in Funafuti. Breadfruit leaves & banana skins make up the majority of composted organic material.

Burning the waste shells and husks from the villages in a gasifier would also sterilise the waste and may help prevent further mite infestation – such as that seen on Vaitupu.

Since the gasifier will be burning organic waste, ash from the combustion of organic material can be added to compost. In addition, as the gasifier would run on waste it would by-pass many of the issues concerned with land use, waste disposal and production of copra for biodiesel electricity generation.

### V.3.5 Options for municipal solid waste (MSW)

As mentioned earlier, waste is a major problem in Tuvalu. It might seem a different issue than the RET's but in many aspects, they run parallel as much of the organic waste ends up mixed up with the other household and commercial rubbish. Currently green waste and coconut shells and husks makes up 70 to 80%+ of what goes to landfill. Much help is also needed for sanitary disposal of MSW, human sewage and pig's manure. This waste could either be composted, used for biogas, producer gas (syngas from gasification) or charcoal.

With no means of recycling imported non-biodegradable packaging, waste such as cans & tins, plastic bags and bottles, glass, non- biodegradable disposable nappies, and composite packaging has quickly filled up the available landfill. There is an aluminium can recycling effort, but since it costs A$ 3500 to send a 10 tonne container back to Fiji, it may not be cost effective. However, there is another individual attempt to collect, compact and ship waste aluminium for recycling. A Fijian Plastic recycling company advertised its opening late 2004. It may offer a more cost effective way to recycle Tuvalu's waste plastics. The Coca Cola-Fiji PET recycling scheme could be another opportunity.

Alofa Tuvalu is supporting the ADB study's recommendations, for example :

- Establish a sustainable composting system;
- Organize community and household waste management program, including separation of wastes by type;
- Separation, collection, and disposal systems for solid waste implemented for all residents on Funafuti Island;
- Design and establish a pump-out system for septic tanks, promote de-sludging service in order to increase demand (Alofa Tuvalu addition : and support the introduction of compost toilets);
- Review current laws and regulations on waste management and prepare a draft solid Waste By-Law;
- Set up a collection area and containers for cans, plastic and glass. Glass Total mass/yr is estimated to be 15-20 tonnes. At a crushed density of $2t/m^3$ this equates to $7\text{-}10m^3$. (This could be used for hard-core & sand by the construction industry);
- Create a "waste/recycling tax" on non-biodegradable packaging and products.

In addition, Alofa Tuvalu's plan for MSW disposal covers several other aspects:

i) To make "retake" agreements with main suppliers and exporters from overseas, for them to be responsible, at least partially, for recyclable items and make use of cargos empty containers going back to Suva;

ii) To facilitate the provision of a bulldozer, one compacter and other tools needed for the exploitation of the current waste management and recycling programs. Alofa Tuvalu had approached the French Foreign Affairs and had raised 50% towards the cost of a replacement bulldozer for the AusAid site. The file had to be dropped, the main problems being: lack of coordination in between funders and difficulty, at the time, in getting the GoT to recognize the waste problem as a priority.

- iii) Educate the general public at all levels about the importance of a clean and toxin-free environment for Tuvalu's well-being and future. School curriculum and awareness raising within the general population via radio announcements, leaflets handed individually and through community and church meetings… In addition, effective waste management options must be provided by the GoT. Regular communication with Kaupule, waste management direction, and the general population to ensure that everyone is aware of what is currently available (such as compost production from organic waste, can recycling, battery disposal etc).

iv) Funafuti has a doorstep waste collection service for which each household pays A$ 30 per year. However, the Kaupule/Town Council has difficulty in collecting remittances and many people do not pay. Many households fail to separate their waste. This could be prevented by the introduction of legislation to fine anyone not separating their waste. This approach has been used by many Local Councils in the UK and it works!!

v) Creating a visitors waste tax (non-residents) bringing up to 50 A$ the present departure tax of A$ 20. The GoT must ensure that revenue raised goes directly to waste management and is not used for other purposes. The revenue raised could pay for waste materials such as plastic, aluminium & glass to be sent via container to re-cycling centres in countries such as Fiji, Australia & New Zealand.

vi) Collecting waste for recycling could be made easier and effective by implementing a "return-deposit" charge on containers such as glass & plastic bottles and aluminium cans. (This would involve making an additional charge, such as 5c per aluminium can which is paid back to the consumer when the can is returned). This would ensure recyclable packaging is returned to the point of sale (or designated collection points) for transportation to a recycling facility. This approach has worked well in Kiribati, and has accounted for a reported 2% increase in GDP as valuable aluminium has been collected, sold and sent abroad for recycling.

Glass is a major problem and is a health risk if not disposed of correctly. It could be separated out of the waste stream going to landfill and used as hardcore to fill the borrow pits (large water filled pits that were dug out during the WWII to build the runway). Before any work can be done though, the Borrow Pits would have to be cleaned, therefore glass bottles and other glass items would have to be stored in containers in a designated area or in a designed for purpose warehouse.

vii) Using tried and tested technologies (such as gasification and digestion) to produce energy from the organic waste component of MSW.

viii) The main effort has to be on not creating as much waste. One way to prevent the build up of non-biodegradable waste is not to import it in the first place. This could be achieved by developing guidelines to ensure only goods wrapped in bio-degradable or economically recyclable packaging are imported into Tuvalu and by banning items such as plastic bags or nappies. Alofa Tuvalu has a project of nappy laundries which could be run by the women of Tuvalu.

In July 2005, an attempt by an Australian association to ban plastic bags failed due to lack of local communication. The organisation came for a couple of days, promised the Tuvalu Cooperative Society to buy back their stock of plastic bags, pulled out the available plastic bags from the stores, handed out some cotton bags and…. left. If a few environmentally aware Tuvaluan people were happy, most of them were surprised and upset not to find plastic anymore. One has to realize that in small islands, plastic bags are used over and over for things like storing fish etc…Today, plastic bags are back in the shops but the Coop manager has decided to import paper and photodegradable plastic bags.
Still, more efforts should be made on choosing imported goods which are biodegradable. Composite materials such as drink & milk cartons are non-biodegradable and difficult to recycle. Suppliers of more environmentally friendly packaging (such as wax-coated cardboard) should be encouraged to supply sort drinks, juices & milk. Polystyrene packaging for take-away foods and drinks should be banned immediately. This type of packaging is not recyclable, does not biodegrade and is banned in many Western countries. By importing this type of packaging, Tuvalu becomes a dumping-ground for materials developed countries no longer welcome.

ix) It is also worth investigating the cost of alternative containers for soft & alcoholic beverages. Soft drinks could be imported as concentrate and compressed gas and "tap" facilities installed at the 5 large shops and 6 bars on the island. Since gas bottles are of high value there may be less cost involved in returning them. Additionally, alcoholic beverages could be imported in large high value aluminium barrels. Coffee and similar items could be imported in large containers/sacks and sold by weigh in stores.

## V.4 WIND ENERGY DEVELOPMENT

Wind energy seems to be a very attractive perspective for three main raisons:

- The technology is mature and available for all ranges of capacity;
- It needs little maintenance;
- The cost of a kWh is cheaper than with oil fired engines as used in Tuvalu.

Alofa Tuvalu's initial analysis of wind potential did not prove positive enough to have confidence in Funafuti's wind potential because:

1 – The potential is very sensitive to any appreciation swerve. Exact values were quite difficult to pinpoint as measurement conditions were not favourable. An additional 12 months of measurements are required from a site close to the area & height of planned generator implementation.

2- Wind potential seems to be both weak and irregular. Present results clearly do not favour maximum production capacity of the turbine: the wind turbine would function only at 14% of its nominal capacity for 8760 hours, which equals only 1233 hours at « nominal » functioning, i.e. diesel generators, or other RET combined would have to insure electricity production for most of the time.

3 – The actual economic reference, the current imported mineral diesel cost for electricity production, remains very high. This should improve with the new Japanese engines (0.21 A$ instead of 0.24 per kWh). Costs per kWh for wind generation, in what we now know are bad conditions, remains low, at around 0.23 A$[22]. If initial investment were to be paid by a foreign donor, the cost per kWh for wind generated electricity would be very low at 0.04 A$. So although wind seems to be weak and irregular it is still five times more cost effective than the planned Japanese electricity generator!!

4 – The question is: what is the capacity for a windmill to best capture weak winds? Transitionally, the first calculations were estimated using Vergnet's widest diameter wings (32 m for a 275 kW maximum power). The result would give a 316 MWh production given the wind patterns in Tuvalu.

5 – In short, wind can be competitive if the wings manage to turn! if new data shows there is enough wind. The situation is highly different than in other countries. However, as Tuvalu has indeed very few valuable resources, research for a solution has to be pursued to a maximum. The next step should be to investigate types of machines which can capture soft winds. One possible way is to use wind turbines with a vertical axis (Darius type) such as the Finnish model "Windside".

6 – It will be possible to draw a final conclusion about the viability of developing wind energy in Tuvalu after one year of wind measurements in optimal conditions and sites.

## V.5 ADOPTION OF SOLAR ENERGY

### V.5.1 Solar PV

In the case of Tuvalu, the real prices for solar PV are still higher than those projected for other developing country markets (shipment, installation and always maintenance costs). The cost of a kWh is, today, more expensive than a kWh from Tuvalu's current means of production – the diesel generators (investment included). These facts have unfortunately caused the withdrawal of existing solar installations when grids where structured in all outer islands except Niulakita. An actual price of imported oil of around 65 US$/bl does not reverse this fact (in 2005).

[22] - or 1 FF/kWh, which is double compared to wind generated electricity in France. But once again, this has to be apprehended in relative values – burning oil for electricity production cost is around 1.12 FF.

If the actual rate of progress for solar PV technology remains the same, the situation will be reversed within ten years. In addition, because other renewables have a greater potential and are cheaper, the development of photovoltaics will be a transition phase for Tuvalu.

In Tuvalu's situation, apart from Niulakita and some off grid remaining networks, PV's future development will mainly consist of Grid connection – whereby solar panels will feed directly into the existing grid rather than developing more stand-alone systemsProgram proposal

Consequently, we are proposing the following policy:

- To give priority to the development engaged on the outer islands,
- To reinforce the country's technical capacity,
- To find a niche in the market where photovoltaic presents a real economic interest,
- To prepare a future phase of development for implementation when the price will be lower.

- ***Funafuti's specific situation***

The new oil generators, ordered in July 2005 for Funafuti, might seem to be closing for a while the door to complementary electricity production - mainly if its production cost is higher. However, it is probable that within 10 years, the electricity request and needs will start to catch up with the new production capacity. Meanwhile the old engines which would have been used as a security will have ended their life span. At this time, a new photovoltaic proposal will find its place all the better if prices have decreased further by then. Research and implementation will have to be done well upstream. It might also be possible that before, imported oil prices would have increased even more – making solar more cost effective. It could also be considered that Tuvalu has to enforce its Kyoto Protocol national plan, solar (along with other renewables) will help Tuvalu achieve this plan. In addition, if the government and people of Tuvalu agree to the « Small is Beautiful » plan (as they have late 2004), a 5 years prospective situation for photovoltaic applications versus oil electricity generation will have to be evaluated.

- ***Complementing the outer islands capacity***

Due to the diesel generation system on Funafuti, the main issue for solar PV is now grid connection on the outer islands.

Photovoltaic development should be pursued in the outer islands as part of a hybrid electric system concept. It can contribute to meet the regular increase needs while an engine using a liquid fuel production is able to supply professional uses, it also satisfies emerging needs such as refrigeration, kettle, washing machine or cooling.

The progress which consisted in previous years to structure a grid in the outer island has to be perceived neither as having given up on photovoltaics nor becoming dependant on diesel. Structuring the grid is a first step to progress that opens the way to an oil free renewable electric system using photovoltaic, copra bio fuel and wind turbines to progressively complement the intermittence of the two first sources.

1000 W modules could provide plenty for the households requests and can support the grid.

***Outer islands electric systems, apart from Niulakita***

The following data concern May 2002 (*12 to get an approximate yearly value). They come from the PIREP report. At that time, the grid was in 17 hours per day on average.

| | Nukulaelae | Nukufetau | Vaitupu | Nui | Niutao | Nanumanga | Nanumea |
|---|---|---|---|---|---|---|---|
| Peak load in kW | 15.3 | 20.7 | 65.1 | 16.2 | 18.3 | 21.6 | 20.3 |
| Number households | 74 | 160 | 206 | 129 | 143 | 125 | 145 |
| Electricity generated in MWh | 51.4 | 68.7 | 261.6 | 57.0 | 52.9 | 61.7 | 81.0 |

**Table 11**- Outer islands electric consumption

This gives a total power of around 177.5 kW and a 634.3 MWh total production. These values can be compared with Funafuti's at a total equivalent population : 1736 kW and 4859 MWh.

In 2002, the Outer Islands used to consume only about 13% of the Funafuti use. When on Funafuti, household average yearly consumption is 1.8 MWh, on the outer islands, it varies in between 0.36 and 0.8 for Vaitupu.

Today often limited to lighting and radio, these numbers show an important consumption increase potential even if tertiary commercial and public sectors are much less important there.

One has to assume that any complementary production must be provided by photovoltaic. Comparing a photovoltaic equivalent tapered power supply to the maximum drawn by the grid would give a power to connect to the grid of about 180 kW, or 180 x 1 kW installations composed of 13 modules of 80 Wp each. This would correspond to a 324 MWh, approximately half of the present consumption. However, production is subject to frequent power breaks and an incapacity to meet needs. Going to PV for this program alone would represent 6.5% of Tuvalu's electric consumption. Such a production would avoid 130 toe oil consumption per year.

Cost of such a program: 2.7 Million A$ at a rate of 15000 A$ per connected kW including investment and installation.

- ***Giving power to isolated households and streetlights***

Photovoltaic becomes interesting each time a small amount of electricity consumption is requested, such as having to dig a road for streetlights. PV street lighting has been running very successfully in Kiribati for several years.

Outer island village and Funafuti street lighting equipment should be photovoltaic. It keeps from having to pull a cable in the ground or to install powermeters to go from the 11 kVA grid power to that required by bulbs.

As an example, the electricity expenditures for street lighting in Funafuti is around 32000 A$ (which should correspond to roughly 100 MWh). As a comparison, it could be replaced by a 56 kW photovoltaic power production, stand-alone street lights (as are used in Kiribati), or 700 x 80 Wc panels.

The Niulakita supply reinforcement, still provided exclusively by photovoltaic has to be put in the same category. Alofa Tuvalu's field visit (2006) examined a rudimentary solar system existing here which is currently operational in only around 50% of households. This system could be vastly improved by the introduction of sealed unit batteries, higher quality light bulbs, and the production of a simple instruction booklet in Tuvaluan outlining basic system maintenance. Currently in Niulakita, solar systems are paid for monthly by the donation of one bag of coconuts per household to be sent and sold to Funafuti for 10 A$ per bag.

For the other islands, a management strategy could be implemented and a small fee could be charged monthly for the replacement of system components as and when necessary.

It would also be quite useful to reinforce the electric supply either with a small windmill or with a biodiesel engine to insure a more constant supply and to allow some telecommunications, professional tools and pumps to work.

- ***Increasing security of vital functions***

When the grid shuts down, it is damaging to many vital public services (meters upset, lost data…). To restore them has a cost and is time consuming. So it is of interest to develop PV for a permanent quality supply as back-up capacity for applications such as telecom, airport instruments, sanitary equipment etc.

- ***Future developments***

In the coming decade, Outer Islands electricity production will have to be expanded as electricity consumption increases. As photovoltaic production is intermittent, this could be done in parallel with biodiesel and biogas electrical production, by either substituting the mineral oil used by the existing engines or by replacing the engines which require investment, for the network/grid management,.

Within the next 10 years, 2 major events will make photovoltaic contribution much more worthwhile in Tuvalu :

Recently acquired generators should see their production capacity progressively caught up to by Funafuti's needs, opening a new path for photovoltaic production capacity increase.

- Secondly, constant photovoltaic development at world level will have decreased costs, making much more attractive the photovoltaic kW cost. The range then should be in between 0.30 and 0.35 per kWh, equivalent to the individual present rate level.
A second photovoltaic development phase would have to be started. If we apply to Funafuti a sizing to fit the actual maximum request, close to 1 MW, we need 1000 x 1kW modules which would produce 37% of the total actual electric consumption

- ***<u>Equipment price range</u>***

The following estimations are based on German market prices. We would get the same numbers on Japanese or Australian markets

- Connected to the grid

Each 80 Wp polycrystalline panel costs 347 Euros, a little less than 600 A$, plus an inverter to get continuous current which costs around 1000 euros, a little over 1500 A$, for a 1000 W unit.

- Off grid systems

One 80 Wp, with a 120 Ah battery and a « regulator » comes to 500 euros/750 A$ plus accessories for a continuous current power supply (prices for subsequent capacity are relatively linear). This puts a kWh around 0.56 A$ which is far from being excessive. The limitation is not the kWh cost but the relatively small electrical production for a relatively large investment. To supply a family off grid, 300 Wc are required to be able to add a small fridge in continuous current such as a boat fridge. This implies a 2000 euros/3000 A$ investment One 250 Ah alone costs 200 euros, i.e approximately 120 A$.

### V.5.2 Solar Thermal

Solar thermal development will insure better living and health in Tuvalu. Either for collective or individual use, it is a well established technology which uses solar radiation directly to heat or boil water, and cook food. It is also one of the simplest RE technologies. For example, it would be enough to paint the hotel water tank black. This would enable it to absorb heat and raise the water temperature at the tap many degrees. Both solar collectors and cookers are relatively cheap and their simplicity insure a long life span and low maintenance costs.

Tuvalu's experience in using solar collectors made of aluminium parts demonstrated that the country requires specialised non-corrosive materials. The simplest solar collectors made of rubber have no glass or metal parts. Solarhart, the Australian manufacturer, could provide the equipment. Implementation would only require technical expertise and backup which could be provided by TMTI, along with training and capacity building. A local company should be established to guarantee installation and provide long term maintenance and management.

Solar collectors for sanitary hot water can be initially installed in medical clinics in the Outer Islands, hotels and restaurants and some public buildings, before becoming more widespread for domestic users. 20 collectors would be enough in an initial implementation phase.

Boiling water with a solar cooker will also likely contribute to reducing oil imports : assuming that the drinking water requirement is 3 litres per person a day, oil savings correspond, on a national level, at 30 t/day i.e. 363 toe per year – (including saving the actual consumption of 76 toe kerosene and 27 toe LPG per year). While some solar hot water units might require a small pump plus electricity (solar) to run them, the total cost should still be lower than current methods. It should be noted that in cases where no additional pump or electricity is needed, solar thermal equipment, collector or cooker, when amortized over only 5 years (with usable lifespan of at least 10), is much less costly than a satellite TV membership over the same period !

# VI CURRENTLY PLANNED FUTURE ACTIVITIES BASED ON REPORT FINDINGS

One of the key requests (and recommendations) for any RET implementation is TRAINING. If the Small is Beautiful project goes ahead as planned, training will be central to and occur throughout the 10 year project period as and when necessary.

## VI.1 The Amatuku initiative

The Chief Officer, heading the TMTI (Tuvalu Maritime Training Institute) in 2005, approached Alofa Tuvalu to initiate biodiesel production on the school islet. This lead to a partnership agreement being established with TMTI to help make Amatuku a "micro-model and training centre for renewable energy technology", a 30 month project.

Should this project go ahead as planned, the Maritime Institute will thus also become a RET National Maintenance and Training Center, the first of its kind in the region. It will support smaller maintenance facilities on Tuvalu's outer islands as well as demonstrate RET's and provide training and back-up for all aspects of RET implementation throughout Tuvalu. This will allow Tuvalu to avoid repeating its past mistakes…and those of other countries in the region when implementing RET's.

The planned objectives of the Amatuku micro-model and training Centre in terms of RET's include the following :

1. Implementation of biogas production based on the use of 2 bio-digesters, one running on the manure of a 35-pig pen and the other on the human waste produced by the TMTI population. The output of the bio-digesters not only will produce methane but the best compost as well. Community gardens will be promoted in conjunction with this activity, as well as composting toilets. The regional organization SOPAC have agreed to provide a biodigester construction specialist.
2. In parallel with the estimation of the current stock of coconut trees, a more detailed analysis of potential biodiesel production and the clarification of the melting, a small biodiesel production plant will be implemented.
3. For wind energy during the 30 months of the micro model project, the objectives are :
   To select site and take measurements for one year to have precise information for the wind generator installation and calculate the expected electricity production. Another option, for demonstration purposes, is to install a small vertical blade windmill which functions with winds starting with as little as 3m/s.
4. Concerning solar energy : The planned ADB renovation does not account for use of solar panels for any of the buildings. Alofa Tuvalu will assess available solar technologies and implement, one or more of the following: a PV system for the grid, solar lighting for external communal areas, and a solar refrigeration system.
5. Solar thermal collector (on ablution block or mess hall roof) for demonstration of hot water production

## VI.2 Policy development

Alofa Tuvalu is participating with GoT and SOPAC representatives in Energy Policy and Strategy Development.

Alofa Tuvalu will continue to help facilitate legislation development concerning issues outlined in this report.

## VI.3 Replication of the Amatuku model

Based on the Amatuku "micro model" and using the training and capacity this project should result in, the wider objectives are to plan and implement larger scale integrated RET's on Funafuti and Outer Islands following the recommendations of this report.

**If implemented, this plan would provide Tuvalu with the practical means of fulfilling GoT's energy policy and of respecting its commitments to international climate change resolutions by abating GHG production. In addition, it would also :**

- **strengthen Tuvalu's case in regional and international climate change negotiations,**
- **reduce its dependence on imported oil, decrease oil imports and provide Tuvalu with increased protection from the whims of the international market,**
- **increase the amount of domestically produced food while decreasing the amount of waste and the volume and cost of food imports,**
- **reduce pollution and run-off, preventing land, sea, and groundwater contamination. Replace soil in areas where it is heavily impacted by salt contamination,**
- **Provide income and much needed jobs, improving quality of life in the outer islands and thereby contribute to the reduction of migration to Funafuti.**
- **reducing the environmental impacts of high population density in Funafuti, and thus improving the well-being in Funafuti as well.**

# VII Annexes

# Annex 1. National Energy Balance for Tuvalu

Prepared from various data sources including United Nations, Energy International Agency. Some subdivisions have been estimated because of lack of desegregated data e.g. electricity end use. It shows a hierarchy of importance between end-uses. All the energy consumption is expressed in tons of oil equivalent (toe; 1toe = 42GJ).

| ***2004*** | **Oil** | | | | **Electricity** | | **Solar** | **Biomass** | **TOTAL** |
|---|---|---|---|---|---|---|---|---|---|
| **toe** | Kerosene | Diesel | Petrol | LPG | | Solar PV | **Thermal** | | |
| ***Primary energy*** | | | | | | | | | |
| Imports | 453.4 | 2638.6 | 624.0 | 43.0 | | | | | 3759.0 |
| National production (harvest for energy) | | | | | | 0.6 | 0.3 | 814.0 | 814.9 |
| Total primary energy | 453.4 | 2638.6 | 624.0 | 43.0 | | 0.6 | 0.3 | 814.0 | 4573.9 |
| | | | | | | | | | |
| ***Transformation*** | | | | | | | | | |
| Thermal electric production | | -1456.0 | | | 417.0 | | | | -1039.0 |
| Electric Production renewables | | | | | 1.0 | | | | 1.0 |
| sub-total electric production | | | | | 412.0 | | | | 412.0 |
| Losses | | | | | 58.0 | | | 125.0 | 183.0 |
| Final Consumption | 453.4 | 1182.6 | 624.0 | 43.0 | 354.0 | | 0.0 | 814.0 | 3471.0 |
| | | | | | | | | | |
| ***Final Consumption*** | 453.4 | 1182.6 | 385.0 | 43.0 | 354.0 | 0.0 | 0.3 | 814.0 | 3232.3 |
| Households | 263.4 | 0.0 | 0.0 | 43.0 | 118.0 | 0.0 | 0.0 | 746.0 | 1170.4 |
| Cooking | *187.7* | | | *16.3* | *6.4* | | | *497.3* | 707.7 |
| Water boiling | *75.7* | | | *26.7* | *11.6* | | | *248.7* | 362.7 |
| Lighting | | | | | *25.0* | | | | 25.0 |
| Refrigeration | | | | | *35.0* | | | | 35.0 |
| Domestic appliances | | | | | *20.0* | | | | 20.0 |
| Other electric appliances | | | | | *10.0* | | | | 10.0 |
| Cooling | | | | | *10.0* | | | | 10.0 |
| Commercial | 20.0 | 0.0 | 0.0 | 0.0 | 130.0 | 0.0 | 0.0 | 68.0 | 218.0 |
| Lighting | | | | | *20.0* | | | | 20.0 |
| Cooking | *20.0* | | | | | | | | 20.0 |
| Refrigeration | | | | | *20.0* | | | | 20.0 |
| Electric appliances | | | | | *10.0* | | | | 10.0 |
| Professionnal uses | | | | | *30.0* | | | 68.0 | 98.0 |
| Cooling | | | | | *50.0* | | | | 50.0 |
| Public services | 0.0 | 0.0 | 0.0 | 0.0 | 106.0 | 0.0 | 0.3 | 0.0 | 106.3 |
| Lighting | | | | | *15.0* | | | | 15.0 |
| Sanitory hot water | | | | | | | 0.3 | | 0.3 |
| Electric appliances | | | | | *14.0* | | | | 14.0 |
| Professionnal uses | | | | | *10.0* | | | | 10.0 |
| Cooling | | | | | *67.0* | | | | 67.0 |
| Transportation | 170.0 | 1182.6 | 385.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1737.6 |
| Air | 170.0 | | | | | | | | 170.0 |
| Fishing | | | 83.0 | | | | | | 83.0 |
| Ships | | 1104.6 | | | | | | | 1104.6 |
| Road | | 78.0 | 302.0 | | | | | | 380.0 |

## Annex 2 – Biomass Energy Potential

As a general definition in the field of energy, **biomass** is all biological material, living or dead, but excludes that which has become fossilised or mineralised. Biomass energy is a renewable energy resource which includes all plant matter (trees, shrubs, crops, forest and crop residues, etc.), animal dung and organic waste which has potential as a source of energy. However, biomass unlike other renewables is a very versatile source of energy which can be converted to modern energy forms such as liquid (bioethanol, biodiesel) and gaseous fuels (biogas – methane), electricity, and process heat.

The term **"Bioenergy"** can be interchanged with the term "biomass energy". However, the term "bioenergy" usually refers to modern biomass energy carriers (such as liquid and gaseous fuels) and usually excludes "traditional" uses of biomass energy such as fuelwood. The term "biofuel" is also commonly used and can refer to ethanol, biodiesel, methanol and other fuels derived from cellulosic & organic waste material.

**Biogas** is a combustible gas derived from decomposing biological waste in an oxygen deprived environment. Biogas normally consists of 50 to 70 percent methane.

Biomass energy sources currently supply around 16% of the world's primary energy making biomass the world's fourth largest energy source. However, much of this energy use is in developing countries where it is in the form of traditional fuelwood, residues and dung which is often inefficiently used and can be environmentally detrimental as well as being deleterious to health when used traditionally and in some domestic appliances.

Biomass resources are potentially the world's largest and sustainable energy source, a renewable resource comprising 220 billion oven dry tonnes (about 4,500 EJ[23]) 1 of annual primary production. The annual global bioenergy potential is estimated to be about 2900 EJ, though only 270 EJ could currently be considered available on a sustainable basis and at competitive prices compared to about 400 EJ of total energy currently being used, (of which biomass represents 55 EJ) (Rossillo-Calle et al., 2005). The problem is not availability but the sustainable management and delivery of energy to those who need it and to provide modern energy services.

The use of biomass as an energy source in the industrial and developing countries could not be more contrasting. In the EU and USA bioenergy is increasingly used in modern applications with the highest rates being 12% of total energy in Austria, 18% in Sweden, 23% in Finland, and 4% in the

[23] 1 EJ = exa Joules; 1018 Joules – the Joule is the System International standard measurement for energy content of a substance.

USA (equivalent to one and half million barrels of oil a day) (RossilloCalle et al., 2005). Traditional uses of biomass in developing countries represents a major proportion of energy (about 30%); this is about 50 EJ or 1190 Mtoe[24]. In the poorest developing countries biomass can comprise a very high fraction of their energy use, mostly in its traditional and highly inefficient forms e.g. Burundi, Ethiopia, Mozambique, Nepal, Rwanda, Sudan, Tanzania, & Uganda all derive over 90% of their energy from traditional biomass. In the world's two most populated countries, India and China, biomass represents 45% and 28% of their primary energy, respectively (Hall et al., 1999).

In the South Pacific region there is great potential for the modernisation of biomass fuels to produce convenient energy carriers such as electricity, gases and transportation fuels whilst continuing to provide for traditional uses of biomass; this is already happening in many countries (e.g. Vanuatu, Fiji, Samoa).

Biomass energy is particularly attractive for decentralised applications where heat, electricity or gaseous fuels are required. Unlike solar or wind systems, modern biomass energy systems can be implemented at virtually any location where plants can be grown. When produced in an efficient and sustainable manner, biomass energy has numerous environmental and social benefits compared with fossil fuels. These include improved land management, waste control, nutrient recycling, use of surplus agricultural land in industrialised countries, job creation, provision of modern energy carriers to rural communities of developing countries, and a reduction of CO2 levels. Among renewable energy sources, biomass is considered an excellent alternative for the substitution of conventional fuels. Thus, for Tuvalu, biomass fuels can form part of a matrix of renewable energy sources that increases the energy available for economic development and gives Tuvalu the potential for energy self-sufficiency, possibly even enabling Tuvalu to export energy in the future. However, biomass energy production and use scenarios are very diverse and that is why it is important to have a reliable assessment of biomass available for energy provision.

In short, biomass energy systems offer an opportunity for sustainable (as biomass can be grown sustainably), self-reliant (biomass is available in all countries and can be converted to liquid fuels and electricity leading to a decrease in imports of oil), and equitable development (between and within countries due to universal availability of biomass and the fact that decentralised bioenergy systems lead to local control and employment).

[24] Mtoe = million tonnes of oil equivalent. 1 tonne of oil has an energy content of approximately 42GJ (GJ = giga Joules = 10 9 J)

Despite this, biomass energy suffers from negative and inaccurate public perceptions; it is also associated with poverty and deforestation and there is little public awareness of modern approaches to bioenergy, and, as is the case with Tuvalu, biomass use does not appear in official statistics and "traditional" uses tend to be ignored. This makes accurate assessment of biomass available for use as an energy source difficult. Many energy industries also see biomass as an inconvenient energy carrier, with dubious net energy production and high costs. In Tuvalu, the awareness of the environmental benefits offered by renewables (other than biomass) relative to fossil fuels is high, particularly with regard to global warming. However, little has been done to implement these technologies. Current biomass energy use appears to be dismissed and ignored. To resolve this issue, the benefits of biomass energy should be emphasised and again brought to the attention of policy and decision makers as well as the wider community.

When considering a large-scale bioenergy programme the following questions need to be addressed:

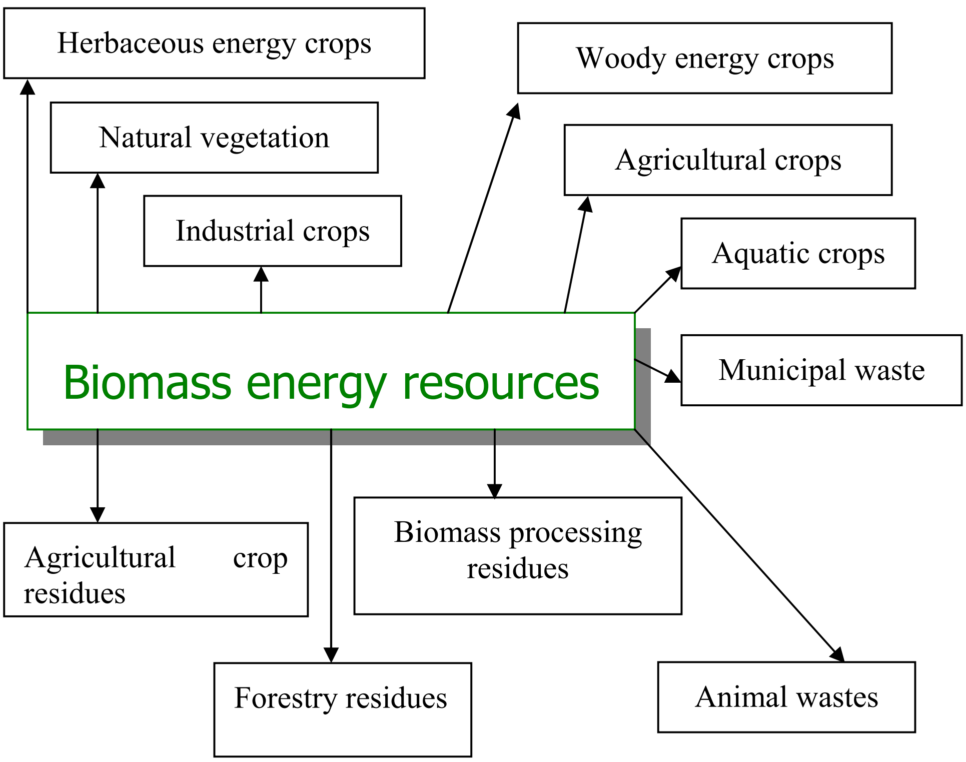
Land availability (short and long-term); Productivities, species and mixtures; Environmental sustainability; Social factors; Economic feasibility; Ancillary benefits; Disadvantages and perceived problems.

Perceived problems, which are particularly relevant for coral atoll agriculture such as that found in Tuvalu, concern nutrient cycling, fertiliser and pesticide requirements, energy input/output ratios, effects on biodiversity and the landscape, possible contributions to erosion, possible conflicts with food production on higher-productivity land, re-planting programmes, and the level of possible subsidies required. Many of these problems diminish if biomass energy is seen as a long term entrepreneurial opportunity for improved land management, based on optimal productivities and organic techniques - using minimum inputs of fertilisers and pesticides.

Biomass energy systems can increase the energy available for economic development without increasing CO2 emissions. Since biofuels will only release the amount of carbon they have absorbed during growth, there are no net carbon emissions associated with their use (providing production and harvesting is sustainable), thereby avoiding carbon emissions from the fossil fuels they substitute for. Biomass fuels also produce lower sulphur and NOx than fossil fuels, and trees can be planted on degraded, deforested and poor quality land helping to rehabilitate it and improve natural resource management.

Despite their wide range of possible sources, biomass energy resources are fairly uniform in many of their fuel properties, compared with competing feedstocks such as coal or petroleum. For example, there are many kinds of coals whose gross heating value ranges from 20 to 30 GJ.t$^{-1}$. However, nearly all kinds of biomass feedstocks fall in the range 15-19 GJ.t$^{-1}$. For most agricultural residues, the heating values are even more uniform – about 15-17 GJ.t$^{-1}$; the values for most woody materials are 18-19 GJ.t$^{-1}$. For biomass moisture content is probably the most important determinant of heating value. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is around 0%. Moisture content is also an important characteristic of coals, varying in the range 2-30%. However, the bulk density (and hence energy density) of most biomass feedstocks is generally low, even after densification – between about 10 and 40% of the bulk density of most fossil fuels – although liquid biofuels have comparable bulk densities (Coconut Oil: energy content between 37 to 43 GJ.t$^{-1}$; Density: 0.91 kg.l$^{-1}$) (Mineral Diesel: 46 GJ.t$^{-1}$; Density: 0.84 kg.l$^{-1}$). (Hall & Hemstock, 1996; Hemstock & Hall, 1995).

**Sources of Biomass Energy**




In Tuvalu there is a large untapped biomass energy potential (e.g. a very conservative estimate based on historical data for copra production (Tuvalu Copra Trading Cooperation, personal communication 2005) suggests that at least 200-300t/yr copra is currently available but unused), this can be further increased with improved utilisation of existing forest and other land resources, higher plant productivity, replanting schemes, and efficient conversion processes using advanced technologies. Therefore much more useful energy could be extracted from biomass than at present. Biomass crops such as high yielding coconut can be grown as part of a national or regional renewable energy strategy. Biomass from various sources (coconuts, pig manure, organic waste, etc.) can then form part of a matrix of fuel sources offering increased flexibility of fuel supply and energy security.

Bioenergy programmes are well suited to Tuvalu as they can be used at small and larger scales in a decentralised manner bringing substantial benefits both to rural and urban areas. Growing biomass is a rural, labour intensive activity and can therefore create jobs and income in the outer islands, reviving the copra market, whilst providing convenient energy carriers which can promote other rural industries. However, none of the benefits of bioenergy will be realised unless biomass can penetrate existing energy markets. All forms of renewable energy compete in markets which are subject to intense regulation, subsidies, legislation, and other distortions. Biomass energy is also affected by the range of policies, subsidies and grants affecting agriculture, forestry and carbon abatement/ climate change. All these factors make costing biomass energy problematic.

For Tuvalu, residues from forestry (re-planting, bush clearance), agricultural activities (pig rearing) and organic waste, as well as coconuts from existing productive trees are invaluable as an immediate and relatively cheap energy resource to provide the initial feedstock in the development of a larger bioenergy industry. This also offers an environmentally acceptable way of disposing of unwanted and often polluting wastes, increasing household income and increasing fuel security - but must encompass environmental sustainability. Thus, for example, the ash from combustion in gasifiers and effluent from digesters can be returned to the land as fertiliser.

## Annex 3– Consultations and interviews in Tuvalu and Fiji

**In Fiji**

**Eugène Berg,** French Ambassador in Fiji
**Taukelina Finikaso,** High Commissioner in Fiji
**Garry Wiseman,** UNDP, Advisor
**David Abbot,** ADB advisor, UNDP advisor
**Maria J Ralha,** European Commission for the Pacific
**Léon Zann,** Université du Pacifique
**Dr. Chalapan Kaluwin,** Forum du Pacifique (Secrétariat du) AMSAT
**Jared Morris,** Forum du Pacifique (import Management Advisor)
**Alvin Chandra**, UNDP, environment / GEF / Energy associate
**Anare Matakiviti,** SOPAC South Pacific Applied Geoscience Commission
**Paul Fairburn,** SOPAC Manager Community Lifelines Programme
**Yogita Bhikabhai,** SOPAC Project Officer PIEPSAP (energy policy)
**Gerhard Zieroth,** SOPAC Project Manager PIEPSAP
**Jan Cloin,** SOPAC energy Adviser
**Aren Baoa,** SCP
**Jyotishma Rajan,** Greenpeace, energy Campaigner
**Tiy Chung,** Greenpeace, communications Officer
**Dale Withington,** WWF Pacifique
**Diane McFadzien,** WWF-climate & energy officer
**Ray Paris,** Pacific risk consulting engineers
**Julie Sutherland,** European Commission for the Pacific, Advisor development

**In Tuvalu**

**Brian Deutrom,** ADB
**Garry Clarke,** Metservice Wellington NZ
**Jonathan Cawood,** EU auditor (business advisory)
**Kiley Humphreys,** Tafe Global, project Manager
**Leonie Smiley,** Canada Aid in NZ
**Maria Luisa Zuniga**, ADB
**Margret Chumg,** ADB
**Mitsuhisa Nishikawa,** Yachiyo Engineering co, Assistant General Manager international division
**Nicky Wrighton**, NZ Aid (2005)
**Roger Wark,** compost specialist, Auckland, ADB Waste survey
**Sirpa H Jarvenpaa,** ADB
**Stéphanie Copus Campbell,** AusAID, Australian High Commission
**Steve Palmer,** met-office UK
**Tony Kortegast,** Tonkin & Taylor ltd, environmental engineering, Auckland NZ, ADB Waste survey

**Tuvaluan Government and directions**

**Aasa Tealofi**, Agricultural Officer, Vaitupu
**Alesana K. Seluka,** Minister of education, sport and culture
**Am Pelosa Manoa Tehulu,** Acting Director of Works (Ministry works/energy)
**Annie Homasi,** Tuvalu Association NGO (Tango)
**Apelamo O'brien,** "solitary recycler"
**Apisai Ielemia**, MP Vaitupu
**Bikenibeu Paeniu,** Minister of Finance and Economic Planning
**Capt. J. Inia**, TMTI, Chief Officer
**Capt. J. Gayton,** Tuvalu Maritime Training Institute (TMTI), Chief Executive Officer
**Dage Kuan**, TMTI, Chief Engineer
**Diana Semi,** Tuvalu Radio journalist
**Emily Koepke,** Family Planning

**Enate Evi,** Director of Environment, Environment department
**Eseta Lauti,** Ministry of Foreign Affairs, Chief of protocol
**Eti Esela,** Crewing Super-intendant**,** Alpha Pacific navigation
**Falagi Reverend,** President AKT church
**Fanoanoaga Patalo,** Ministry of Home Affairs and Rural Development, Outer islands
**Father Camille Desrosiers**
**Fiafiaga Lusama,** TTC, Technician trainee
**Fialua I Monise**, Agriculture Dept. Vaitupu
**Filipo Taulima,** Director Public works department
**George Selupapelu**, Nukufetau Kaupule Coconut Mill
**Hellani Tumua,** head of Kaupule, Town Council
**Hilia Vavae,** Tuvalu Meteorological Service, Director
**Ian Fry**, environmental Consultant
**Isaia Taape,** Deputy Secretary, Ministry of works/energy
**Itaia Lausaveve,** Permanent Secretary, Ministry of agriculture
**James M. Conway,** advisor
**Joane M Pauli**, Kaupule Secretary, Vaitupu
**John Hensford (capt),** Alpha Pacific navigation Manager
**Kapuafe Lifuka,** energy technical Officer
**Katalaimia Malua,** President Tuvalu National Council of woman
**Kelesoma Saloa,** National Piggery Project and International Waters Project for small Island States
**Kitiona Tausi Reverend,** General Secretary AKT
**Koan Dage**, TMTI engineer
**Kulene Sokotia,** Land survey
**Leauma Liai,** TCS auditor
**Letasi Iulai,** Senior Economic Adviser, Economic Planning & Industries
**Leti Pelesala**, Minister of Home Affairs and Rural Development
**Lina Salataka,** department of environment
**Luke Danielu**, ex cancare
**Luke Paeniu**, Head of Tuvalu Chamber of Commerce
**Maatia Toafa,** Prime Minister
**Mafalu Lotolua,** Tuvalu Electricity Corporation, General Manager
**Malie Lototele**, Director of Economic Research and Policy Division
**Malofou Auina,** Community affairs officer
**Melali Taape,** Tuvalu Media Corporation, Manager
**Mika,** Manager Tuvalu BP Oil
**Misalaima Nelesone,** permanent Secretary works
**Molipi Tausi,** energy Planner
**Monise Laafai,** Tuvalu Coop Society (TCS), Manager
**Nala Ielemia**
**Panapasi Nelesone,** Secretary to Government, Office of the Prime Minister
**Pasivao Maani**, TCTC
**Paulson Panapa,** PM Office
**Peitala,** Canada Aid representative
**Pennilei Metia,** General Secretary Tuvalu National Council of Women
**Pepetua Laatasi,** Climate change
**Pesemeta,** Ausaid
**Poni Falae**, NAPA, Adapt program
**Pulafagu Toafa,** Tuvalu National Council of woman, Coordinator
**Pusinelli Aufai,** permanent Secretary energy
**Rev Tofiga Falaui and Vaieli,** head of Funafuti women community
**Samuelu P. Teo**, Minister of Natural Resources
**Saufatu Sopoaga,** Minister of Energy, Transports, Works and Communication

**Seluka Seluka,** sustainable agriculture, DSAP
**Semese Alefaio,** Funafuti Marine Conservation Area
**Semu Malona,** Government statistician
**Senilily Pasefika,** PDL
**Seve Lausaveve**, permanent Secretary transport
**Seve Paeniu,** ex-permanent Secretary Ministry of finance
**Siava,** head of Women Nuitao community
**Silafaga Lalua,** Tuvalu Echoes
**Siuila Toloa,** teacher, President of Island Care, Milo Akoi
**Sivaga Filolita**, Motufoua Sec. School
**Solofa Uota,** permanent Secretary (2005), education, sport and culture
**Susan Tupulaga,** head of Waste Management
**Susie Saitala Kofe,** RRRT (legal right training Officer)
**Tafui Lusama,** Reverend AKT officer
**Tammy**, Mama's Petrol Station
**Tauala Katea,** Tuvalu Meteorological Service, scientific Officer
**Tekaai Nelesone,** Chairman Tuvalu Hospital
**Temukisa Hauma,** school principal
**Tesio M. Nill**, TCTC Manager, Vaitupu
**Teuleala Manuella,** Community affairs officer, Social Works
**Timaio Auega**, ex TSCES (Tuvalu)
**Timaio Auega,** renewable energy research Officer
**Tito Isala,** PM Office
**Toaripi Lauti,** 1er Premier Ministre à l'Indépendance
**Tomalu Talu,** TTC, Earth station duty technician
**Tuafafa Latasi,** Recycling Cancare
**Tuitupe Puava,** acting head teacher
**Utala Taloka,** engineer at Naficot
**Vaililo Lito,** Tuvalu Telecommunications Corp. (TTC) Manager Administration
**Vaiolata Luni**, Nukufetau
**Vavao Samonaia,** Waste Management
**Yvette D'Unienville,** Tuvalu Radio journalist

Not included in this list : 300 women, 200 coconut/copra producers, consulted during community meetings held to get data and promote biogas and biodiesel, and a few hundred Tuvaluan friends or acquaintances who also support RET's in Tuvalu.

# Annex 4– Bibliography

TUVALU 2002 Population and Housing Census. Volume 2: Analytical Report

Demographic Profile of Tuvalu- 1991-2002

TUVALU 2002 Economic and Public Sector Review By Bruce Knapman, Malcolm Ponton, and Colin Hunt For the Asian Development Bank

Social and Economic Wellbeing Survey -Tuvalu 2003 Dianne Buchan & Chris Cosslett , Nimmo-Bell & Co, ADB TA No. 3221-TUV, Island Development Program Implementation

SOCIAL DEVELOPMENT POLICY FOR TUVALU, Presentation to the National Women's Conference, March; 2004, By Teuleala Manuella Community Affairs Officer

Quarterly Statistical Reports, December Quarter 2004- August 2005, December Quarter 2003-May 2004, Government of Tuvalu, Ministry of Finance, Economic Planning & Industries,

TUVALU COOP TB Ann KPMG 03-04 account tables

Petroleum in-country workshop report Nov 2004, Prepared for Tuvalu Ministry of Works and Energy Tuvalu By Jared Morris Pacific Islands Forum Secretariat

THE TUVALU MARITIME TRAINING INSTITUTE- SUMMARY– ADB-TRIPARTITE MEETING- 2001 Submitted by John Carter, Ray Greer, Julian Joy, Ray Paris, Simon Reid,

TUVALU, By Herbert Wade September 2004 for PIREP

National Energy Policy Framework – Tuvalu Inception Report. SOPAC, Matakiviti, A. (2004).

SOPAC (2002) Sustainable Development Strategy, SOPAC.

EFFECTIVE WASTE MANAGEMENT AND RECYCLING IN TUVALU, TA No. 4214 – TUV, INCEPTION REPORT, (Final Draft), 17 JULY 2004, by TONKIN & TAYLOR INTERNATIONAL LTD, for The ASIAN DEVELOPMENT BANK

Pacific Regional Energy Assessment 2004 , An Assessment of the Key Energy Issues,
Barriers to the Development of Renewable Energy to Mitigate Climate Change, and Capacity
Development Needs for Removing the Barriers

FACILITATING ADAPTATION TO CLIMATE CHANGE IN THE SOUTH PACIFIC REGION – BRIDGING RESEARCH, POLICY, AND IMPLEMENTATION *Introductory Seminar on* CLEAN DEVELOPMENT MECHANISM IN THE PACIFIC ISLAND COUNTRIES – © 2004 Institute for Global Environmental Strategies.

Trewren, K. (1984) Coconut Development in Tuvalu. Ministry of Commerce & Natural Resources, Funafuti, Tuvalu.

Technical Report-Tree crops report Tuvalu 1985, 1986 by K Trewren

Department of agriculture annual reports TUVALU 1983, 1984

Department of Agriculture National accounts Tuvalu 1988-90

Chanakya, H. N., Bhogle, S., Arun, R. S. (2005). Field experience with leaf-litter based biogas plants. Energy for Sustainable Development. IX2, 49-62.

Dept. of Lands & Survey (Tuvalu), (2004). Geographical Information showing Land Areas of the Islands of Tuvalu.

Hall, D. O.; Rosillo-Calle, F. (1999). EVALUATING ENVIRONMENTAL EFFECTS AND CARBON SOURCES AND SINKS RESULTING FROM BIOMASS PRODUCTION AND USE IN DEVELOPING COUNTRIES. *Pergamon Press.*

Hall, D. O., Hemstock, S. L. (1996). Biomass Energy Flows in Kenya and Zimbabwe - Indicators of $CO_2$ Mitigation Strategies. *The Environmental Professional* 18, 69-79.

Hemstock, S. L., Hall, D. O. (1995). Biomass Energy Flows in Zimbabwe. *Biomass and Bioenergy* 8, 151-173.

Overend, R. P., (2003). Heat, power and combined heat & power. BIOENERGY OPTIONS FOR A CLEANER ENVIRONMENT. Chapter 3. Elsevier Ltd.

Ravindranath, N. H., Somashekar, H. I., Dasappa, S. Reddy, C. N. J. (2004). Sustainable biomass power for rural Indis: Case study of biomass gasifier for village electrification. Current Science, 87, 932-941.

Rossillo-Calle, F.; Hemstock, S. L.; Woods, J.; De Groot, P. (2005) Handbook of Biomass Energy Assessment. Earthscan Publications. (in press).

UNDP, (2002) Biomass Energy Primer.

Woods, J., Baun, A., (2003). Technology Status Review and Carbon Abatement Potential of Renewable Transport Fuels (RTF) in the UK. Imperial College London, Centre for Energy Policy and Technology (ICCEPT). UK Department for Trade and Industry (DTI).

Woods, J., Baun, A., Hailes, R. (2003).Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020. Centre for Energy Policy and Technology, Imperial College London and E4tech (UK) Ltd. WWF International Report.

Woods, J., Hemstock, S. L., Bunyeat, J. (2005). Bio-energy systems at the community level in the South Pacific: impacts & monitoring. Greenhouse Gas Emissions and Abrupt Climate Change: Positive Options and Robust Policy. IEA Expert Workshop, Paris, 30th Sept – 1st October, 2004. *Journal of Mitigation and Adaptation Strategies for Global Change (*accepted).

Woods, J., Rosillo-Calle, F. and Hemstock, S. (2003) *Consultancy for SOPAC – South Pacific Applied Geoscience Commission on*: A master development plan for the biomass resources of: Fiji, Kiribati, Samoa, Tonga, Tuvalu and Vanuatu. ICEPT/EPMG, Dept of Environmental Science and Technology, Imperial College London.