# Renewable Energy on Small Islands

## Second edition

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# Renewable Energy on Small Islands

## Second Edition

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| **Cover photos:** | Upper left: | A 55 kW wind turbine of the Danish island of Aeroe. Photo provided by Aeroe Energy and Environmental Office. |
| | Middle left: | Solar water heaters on the Danish island of Aeroe. Photo provided by Aeroe Energy and Environmental Office. |
| | Upper right: | Photovoltaic installation on Marie Galante Island, Guadeloupe, French West Indies. Photo provided by ADEME Guadeloupe. |
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# Foreword and Acknowledgements by the author Mr. Thomas Lynge Jensen, Forum for Energy and Development (FED), Denmark

## First Edition

The first edition of Renewable Energy on Small Islands was published in April 1998 and was financed by the Danish Council for Sustainable Energy.[1] The background for the report was the decision by the Danish Government to establish an official Renewable Energy Island (REI) – i.e. an island that will become 100% self-sufficient from renewable energy sources. In November 1997 Samsoe was selected – among 5 candidates – to become the official Danish REI.

The overall objective of the overview of renewable energy on small islands was to prepare for future global co-operation and networking among REI's.

## Second Edition

Since the first edition much more and adequate information has been available (e.g. due to two major conferences) and major initiatives have been announced (e.g. the announcement of two Renewable Energy Island Nations). Therefore is a second edition needed.

This second edition includes new cases and up-dated information on cases from first edition. In relation to some of the cases from first edition it has not been possible to obtain up-dated information. These cases are summarised in appendix 1 to this second edition.

This second edition is financed as part of the project Global Conference on Renewable Energy Islands. The conference was held on the Danish Island of Aeore the 15-16 September 1999 and was financed by the European Commission (SYNERGY-programme), the Danish Energy Agency, the Danish Council for Sustainable Energy and Forum for Energy and Development (FED).[2]

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## The Report is Available on the Internet and by e-mail

This report can be downloaded in PDF-format on the Internet at the homepage of Forum for Energy and Development (FED):

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[1] The report can still be downloaded in PDF-format from the homepage of Forum for Energy and Development (FED): http://www.energiudvikling.dk/projects.php3

[2] The proceedings can be downloaded in PDF-format at the homepage of Forum for Energy and Development (FED) : http://www.energiudvikling.dk/projects.php3

# Introduction

## Objectives

The overall objectives of this overview are to:

► document that renewable energy is a feasible option on islands in regard to environment, technology, organisation, economics etc.

► facilitate global co-operation and networking among Renewable Energy Islands, i.e. islands that have decided to become 100% self-sufficient from renewable energy sources

## Scope of the Report

The report is a global overview of renewable energy utilisation and initiatives on small islands.

The report includes descriptions of:

► already implemented and still functioning renewable energy projects; and

► current and future plans for renewable energy developments on small islands.

More specific the overview will - where possible - include a description of the islands in regard to; size; population; energy consumption; energy supply in regard to technology, organisation, financing, and education; current and future plans for renewable energy developments; and relevant contact information.

The scope of the report is descriptive in content, but the Executive Summary does include some more evaluative and normative elements.

## Terminology

An **island** is "a land mass smaller than a continent that is surrounded by water".[1] The term "island" in this report do *not* cover submerged areas, land areas cut off on two or more sides by water (such as an peninsula), or areas land-tied by dam or bridge.

A **Renewable Energy Island (REI)** is an island that is 100% self-sufficient from renewable energy sources, including transport.

A **small island** have in this report been delimited to an island that is the size or smaller than 10,000 km$^2$ i.e. the size of the island of Hawaii.

## Methodology

This report is *primarily a desk study based on already available information*. A minor part of the information contained in this report is based on questionnaires and personal communications.

Most of the island presentations are "pieced together" by using several different references. This means that a specific reference utilised at a given paragraph/moment is not made explicit – this would be too cumbersome. The only exception is when tables are presented – then references are made explicit. References utilised are mentioned in the end of each of the island presentations and ordered alphabetically. Detailed information about the references can be obtained in chapter 10. References.

To keep the information as accurate as possible in most *cases direct transcript of the references has been used.* We hope that the authors of the different references can accept this procedure.

## Precautions

There are some precautions that are important to keep in mind when reading this report or using some of the information:

► Even though the perspective of this report is global it does of course not imply that the findings are exhaustive - it only means that the report includes cases from all over the world. The report does *not* pretend to have included all the existing small islands with utilisation or present or future initiatives in regard to renewable energy.

► Renewable energy utilisation and initiatives have been delimited *to modern renewable energy technologies*. E.g. islands that have their energy needs covered from more traditional renewable energy technologies such as burning of biomass for cooking are not mentioned in this report.

► There is a *big* diversity regarding how detailed the presented information is. This is due to the fact that a great number of different sources and references have been used.

[1] Wordnet 1.6 (www.cogsci.princeton.edu/~wn)

► *Some data are not up-to-date*. As a guiding principle it has been chosen to use information dating back from 1995 and onward.

► Neither Forum for Energy and Development (FED), nor the European Commission or the Danish Energy Agency, do not make any warranty, expressed or implied, with respect to the information contained in this report or assumes any liabilities with respect to the use of this information.

► The European Commission or the Danish Energy Agency do not necessarily share the views expressed in the Executive Summary.

**Structure of the Report**

The following are the main categories for ordering and presenting the islands[2]:

► The North Atlantic Ocean
► The South Atlantic Ocean
► The Baltic Sea
► The Mediterranean Sea
► The Indian Ocean
► The North Pacific Ocean
► The South Pacific Ocean
► The Caribbean Sea

The islands are ordered alphabetically in each of these categories.

[2] This categorisation of the oceans and seas of the world are off course not complete – e.g. the North Sea is included as part of the North Atlantic Ocean. The reason is to obtain clarity.

# Executive Summary

## Introduction

The last few years has shown an increased focus of renewable energy on islands. A few examples: in 1997, Samsoe was announced the official Danish Renewable Energy Island (REI); in 1999, the first Global Conference on Renewable Energy Islands took place; in 1999, the Global Secretariat on Renewable Energy Islands was established and in 2000, two nations in the Caribbean - St. Lucia and Dominica - announced their intentions of becoming renewable energy nations.

However in nearby all of the islands around the world the potential for renewable energy is not yet tapped. For the majority of islands expensive and environmentally problematic fossil fuels are still the only energy sources utilised.

One of the reasons for the under-exploitation of renewable energy is lack of knowledge and awareness. Lack of knowledge and awareness about the few islands around the world that today actually have substantial utilisation and experiences in regard to renewable energy, the very big potential of renewable energy resources on islands, the maturation of renewable energy technologies, their competitiveness especially in island context, organisational models for planning, implementation, ownership, financing etc.

Consequently one of the objectives of this overview is to document that renewable energy on islands is a feasible option in regard to environment, technology, organisation, economics etc.

The other main objective is to facilitate global co-operation and networking among Renewable Energy Islands. More networking and joint co-operation among islands with a strong ambition in regard to renewable energy may significantly strengthen the role of islands as global forerunners for renewable energy.

## Main Findings

Based on tables 1-6 presented in the end of this section (pp. viii-xii) the following can be concluded regarding the islands in the overview:

<u>Around the world a few islands already have taken the decision to become a Renewable Energy Island (REI) in the short or medium term.</u>

Samsoe (Denmark), Pellworm (Germany), Aeroe (Denmark), Gotland (Sweden), El Hierro (Spain), Dominica and St. Lucia have an explicit target of becoming 100% self-sufficient from renewable energy sources.

<u>Around the world a few islands already have some of the characteristics of a Renewable Energy Island (REI)</u>

La Desirade (France), Fiji, Samsoe (Denmark), Pellworm (Germany) and Reunion (France) are currently producing more than 50% of their electricity from renewable energy sources

21% of the islands in the overview that are utilising renewables for electricity generation are producing between 25-50% of their electricity from renewable energy sources.

Nearly 70% of the islands in the overview that are utilising renewables for electricity generation are producing between 0.7-25% of their electricity from renewable energy sources.

A few islands are using solar water heaters on a very large scale (Barbados and Cyprus).

<u>Islands with very big utilisation of renewable energy for electricity production are mainly utilising hydropower.</u>

In the overview more than 50% of the islands with more than 25% of the electricity generated from renewable energy resource are utilising hydropower.

Of the islands producing more than 25% of the electricity from wind power all are (but one) connected by sea cable to another electricity grid.

Wind power is by far the most utilised renewable energy resource utilised for electricity production.

Over 50% of the islands in the overview that have utilised renewables for electricity generation have used wind power.

Over 25% and nearly 10% of the islands in the overview utilising renewables for electricity generation have utilised hydropower and biomass respectively.

Most islands are situated in the North Atlantic Ocean.

Just over 40% of the islands in the overview that have utilised renewables are situated in the North Atlantic Ocean.

Around 12-14% of the islands in the overview that have utilised renewables is situated in the North Pacific Ocean, South Pacific Ocean and Caribbean Sea respectively.

By far the majority of islands are non-sovereign.

Nearly 75% of the islands in the overview that have utilised renewables are connected formally to a country from the developed world.

Only 25% of the islands in the overview that have utilised renewables are politically independent islands - they are all developing countries.

**Why Islands are Important for the Promotion of Renewable Energy World-wide**

On a global scale islands are relatively small considering size, population, energy consumption, emission of greenhouses gasses etc. But why then are islands important when it comes to the promotion of renewable energy world-wide? Why can islands in particular be global front-runners and show-cases for renewable energy technologies and show the way to a sustainable energy future? There are several interrelated answers.

High Visibility:

Islands are land areas surrounded by water. This means they are well-defined entities not only speaking of geography, but also in terms of energy production, population, economy and so forth. Thus, islands can become highly visible laboratories for renewable energy technology, organisation, and financing. REI's are a very useful way to make future energy-systems visible and concrete.

Need for Demonstration of Renewable Energy in an Integrated and Organised Form:

If decision-makers world-wide should be inspired to aim at a broader use of renewable energy as part of a sustainable development, it is necessary to demonstrate renewable energy in a large-scale, integrated and organised form, and placed in a well-defined area - i.e. a REI.

Large Scale Utilisation of Renewable Energy Possible on Islands

A dramatic shift to renewable energy on a large scale on continents/mainlands is unrealistic in the short and medium term in regard to technology, financing and organisation. However it would be of high interest to demonstrate the possibilities of smaller communities to base their entire energy supply on renewable energy sources. Islands can cheaper, faster, and easier reach a higher share of renewable energy in its energy balance than a much bigger mainland. The very smallness of the islands – that often is seen as a disadvantage – is in this context actually an advantage.

More Progressive Attitudes towards Renewable Energy:

Many islands have positive attitudes towards the utilisation of renewable energy also on the political level.

One reason being the threat from global warming. Even though islands contribute only negligible to global emission of greenhouse gasses, many islands around the world are among the immediate victims of climate change and instability caused by fossil fuel consumption in industrialised countries. Islands thus have a strong interest in changing energy patterns for instance by demonstrating new sustainable ways of satisfying energy needs.

Another reason for the more progressive attitude found on islands is the near total absence of fossil fuel resources on islands. In many mainland countries, developing as well as industrialised, one major barrier for promotion of renewable energy resources is the presence of an economic and political elite that has very strong interests in the utilisation of the countries fossil fuels resources either for export or domestic purposes. Most islands' main resources are the ocean, the population and the geography for tourism. Next to none have fossil fuel resources.

Competitive Advantage:

Most small islands around the world today are dependent on imported fossil fuels for their energy needs, especially for transport and electricity production. Because of the small size and isolated location of many islands, infrastructure costs such as energy are up till three to four times higher than on the mainland. The high price for fossil fuels combined with the limited demand increases the unit cost of production for conventional power production. This creates a competitive situation for renewable energy technologies on islands. Furthermore, most of the islands are endowed with good renewable resources, primarily sun and the wind.

Experiences Applied in non-island Areas:

Experiences gathered on islands can be used, not only on islands, but in principle everywhere. REI's can serve as demonstration projects for mainland local communities, not only in developed countries, but also in developing countries. There are about 2.5 billion people living outside a national grid in developing countries. These people also need electricity services and experiences from REI's are highly relevant in this context.

Furthermore, through concentrated efforts some small island states can serve as demonstration nations. Despite their size small island states could set an example to the world's nations.

**Conclusion**

Today nearly all islands in the world are totally dependent on expensive and environmentally problematic fossil fuels for their energy needs.

But islands have a unique potential for renewable energy - a competitive economic situation for renewable energy technologies, good renewable energy resources, positive attitude towards renewable energy, highly visible laboratories for technology, organisational methods and financing and serve as demonstration projects and nations.

At the same time globally there is a need to demonstrate renewable energy in a large-scale, integrated and organised form. This is not possibly on mainland and continents in the short and medium term for economically, technically and organisational reasons. Therefore islands are very important and interesting when it comes to the promotion of renewable energy world-wide.

Today a very few islands already have some of the characteristics of a Renewable Energy Island and thereby use renewables extensively. Some islands have utilised renewable energy on a big scale. Some islands have set targets of becoming a Renewable Energy Island in the short or medium term and St. Lucia and Dominica have declared their intentions to become the first Renewable Energy Nations. All of the mature renewable energy technologies have been utilised for electricity production on islands. Small islands as well as big islands in regard to area, population and power system have utilised renewables and islands in all regions and climates are utilising renewables. Islands in the developing as well as developed world have experiences with renewable energy. Consequently, there is good potential for future co-operation, exchange and networking among islands – both between islands that are very far on the path of converting their energy systems into sustainable energy systems and between islands that have just started.

## Table 1: Renewable Energy Share of Electricity Production for Investigated Islands [1]

| Island | Total Percentage of Electricity Production from Renewable Energy Sources | Percentage of Electricity Production by Type of Renewable Energy Source | | Year | Island Connected to other Electricity Grid | Renewable Energy Goal/Plan/ Strategy | Area | Population |
|---|---|---|---|---|---|---|---|---|
| **La Desirade (Guadeloupe, France)** | 100% | Wind: | 100% | 1998 | Yes | There is a renewable energy plan for the Guadeloupe archipelago – 25% of the electricity consumption from renewable energy in 2002 | 70 | 1,610 |
| **Fiji** | 79.6% | Hydro: | 79.6% | 1997 | No | There is a national energy/renewable energy policy | 18,376 | 802,611 |
| **Samsoe (Denmark)** | 75%[2] | Wind: | 75% | 2000 | Yes | 100% of energy consumption from renewable energy sources by 2008 | 114 | 4,400 |
| **Pellworm (Germany)** | 65.93% | Wind:<br>PV: | 64.96%<br>0.97% | 1998 | Yes | 100% of energy consumption from renewable energy sources | 37 | 900 |
| **Reunion (France)** | 56.1% | Hydro:<br>Bagasse: | 39.6%<br>16.5% | 1998 | No | | 2,512 | 653,000 |
| **Dominica** | 48% | Hydro: | 48% | 1998 | No | 100% of energy consumption from renewable energy sources in 2015. A national energy policy does not exist today | 977 | 71,183 |
| **Flores Island (Azores, Portugal)** | 42.6% | Hydro: | 42.6% | 1999 | No | | 141.7 | 4,329 |
| **Samoa** | 38.5% | Hydro: | 38.5% | 1997 | No | Samoa does not have a comprehensive energy policy | 2,831 | 235,302 |
| **Sao Miguel Island (Azores, Portugal)** | 37.6% | Geothermal:<br>Hydro: | 30.6%<br>7% | 1999 | No | | 746.8 | 125,915 |
| **Faeroe Islands (Denmark)** | 35.1% | Hydro:<br>Wind: | 34.9%<br>0.2% | 1999 | No | There is no energy plan for the Faeroe Islands | 1,400 | 48,000 |
| **St. Vincent and the Grenadines** | 32.8% | Hydro: | 32.8% | 1997 | No | The is no national energy policy | 389 | 181,188 |
| **Marie Galante Island (Guadeloupe, France)** | 30% | Wind: | 30% | 1998 | Yes | There is a renewable energy plan for the Guadeloupe archipelago – 25% of the electricity consumption from renewable energy in 2002 | 158 | 13,463 |
| **Corsica (France)** | 30% | Hydro: | 30% | 1999 | Yes | 50% of electricity consumption from renewables by 2003 | 8,721 | 249,733 |

[1] A blank cell means that information is not available

[2] Estimation from July 2000 and onwards.

| Island | Total Percentage of Electricity Production from Renewable Energy Sources | Percentage of Electricity Production by Type of Renewable Energy Source | Year | Island Connected to other Electricity Grid | Renewable Energy Goal/Plan/ Strategy | Area | Population |
|---|---|---|---|---|---|---|---|
| **Miquelon (St. Pierre and Miquelon, France)** | 30%[3] | Wind: 30% | 2000 | | | | |
| **Hawaii Island (Hawaii, USA)** | 29% | Geothermal: 22.3%<br>Hydro: 5%<br>Wind: 1.7% | 1997 | No | There is a energy/renewable energy strategy for Hawaii State | 10,433 | 120,317 |
| **King Island (Australia)** | 20% | Wind: 20% | 1999 | No | | 1,250 | 1,800 |
| **Kauai Island (Hawaii, USA)** | 21.1% | Biomass: 17.3%<br>Hydro: 3.8% | 1997 | No | There is a energy/renewable energy strategy for Hawaii State | 1,430 | 50,947 |
| **Rarutu Island (French Polynesia)** | 20%[4] | Wind: 20% | 2000 | No | | 243 | 2,000 |
| **Mauritius** | 19.37% | Bagasse: 10.35%<br>Hydro: 9.02% | 1996 | No | | 2,040 | 1,196,172 |
| **Madeira Island (Madeira, Portugal)** | 17.4% | Hydro: 15.2%<br>Wind: 2.2% | 1998 | No | There is a regional energy plan | 765 | 248,339 |
| **Ascension Island (UK)** | 16% | Wind: 16% | 1997 | No | | 82 | 1,100 |
| **Gotland (Sweden)** | 15% | Wind: 15% | 1999 | Yes | 100% of energy consumption from renewable energy sources | 3,140 | 58,000 |
| **Isle of Pines (New Caledonia, France)** | 15%[5] | Wind: 15% | 2000 | No | | 141.4 | 1,700 |
| **Sal Island (Cape Verde)** | 14%[6] | Wind: 14% | 1995-1997 | No | | 298 | 10,168 |
| **Sao Vicente Island (Cape Verde)** | 14%[7] | Wind: 14% | 1995-1997 | | | 246 | 63,040 |
| **Maui Island (Hawaii, USA)** | 13.1% | Biomass: 11.1%<br>Hydro: 2% | 1997 | No | There is a energy/renewable energy strategy for Hawaii State | 1,883 | 100,374 |
| **St. Helena (UK)** | 13%[8] | Wind: 13% | 1999 | No | | 122 | 5,564 |
| **Aeroe (Denmark)** | 12.7% | Wind: 12.7% | 1999 | Yes | 80-100% of energy supply from renewable energy over a period of 10 years from 1998 to 2008 | 90 | 7,600 |
| **San Clemente Island (USA)** | 10.6% | Wind: 10.6% | 1998 | No | | 137 | n.a |
| **Sao Jorge Island (Azores, Portugal)** | 10.3% | Wind: 10.3% | 1999 | No | | 245.6 | 10,219 |

[3] Estimation.
[4] Estimation.
[5] Estimation.
[6] The penetration is for the Sal power system, which is the main power system on Sal Island.
[7] The penetration is for the Mindelo power system, which is the main power system on Sao Vicente Island.
[8] From June-December 1999.

| Island | Total Percentage of Electricity Production from Renewable Energy Sources | Percentage of Electricity Production by Type of Renewable Energy Source | | Year | Island Connected to other Electricity Grid | Renewable Energy Goal/Plan/ Strategy | Area | Population |
|---|---|---|---|---|---|---|---|---|
| **Guadeloupe (France)** [9] | 9.3% | Biomass:<br>Hydro:<br>Geothermal:<br>Wind: | 7%<br>1%<br>1%<br>0.3% | 1999 | No[10] | 25% of the electricity consumption from renewable energy in 2002 | 1,709 | 421,600 |
| **Fuertenventura Island (Canary Islands, Spain)** | 8.6% | Wind: | 8.6% | 1999 | No | | 1,660 | 41,629 |
| **Thursday Island (Australia)** | 8% | Wind: | 8% | 1997-1999 | No | | 4 | 4,000 |
| **Sao Tiago Island (Cape Verde)** | 6.3% | Wind: | 6.3% | 1995-1997 | No | | 992 | 210,932 |
| **Graciosa Island (Azores, Portugal)** | 6.9% | Wind: | 6.9% | 1999 | | | 60.9 | 5,189 |
| **Crete (Greece)** | 5.5% | Wind:<br>Other: | 5%<br>0.5% | 1999 | No | 45.4% of the total annual electricity demand in 2010 by renewable energy sources | 8,260 | 540,054 |
| **La Palma (Canary Islands, Spain)** | 5.5% | Wind:<br>Hydro: | 4.8%<br>0.7%[11] | 1999 | No | There is a energy/renewable energy plan for the Canary Islands | 708 | 81,521 |
| **Porto Santo Island (Madeira, Portugal)** | 5.5% | Wind: | 5.5% | 1998 | No | There is a regional energy plan | 42 | 5,000 |
| **Oahu Island (Hawaii, USA)** | 5% | Municipal Solid Waste:<br>Biomass: | 4.8%<br>0.2% | 1997 | | There is a energy/renewable energy strategy for Hawaii State | 1,554 | 836,207 |
| **El Hierro (Canary Islands, Spain)** | 4.2% | Wind: | 4.2% | 1999 | No | 100% of electricity supply from renewable energy | 269 | 8,338 |
| **Grand Canary Island (Canary Islands, Spain)** | 4% | Wind: | 4% | 1999 | No | There is a energy/renewable energy plan for the Canary Islands | 1,560 | 714,139 |
| **Lanzarote Island (Canary Islands, Spain)** | 3.2% | Wind: | 3.2% | 1999 | No | There is a energy/renewable energy plan for the Canary Islands | 846 | 77,233 |
| **Santa Maria Island (Azores, Portugal)** | 3% | Wind: | 3% | 1999 | | | 97.1 | 5,922 |
| **Curacao (Netherlands Antilles, The Netherlands)** | 2%[12] | Wind: | 2% | 1999 | | | 444 | 143,816 |
| **Tenerife (Canary Islands, Spain)** | 1.57% | Wind:<br>Hydro: | 1.55%<br>0.02%[13] | 1999 | | There is a energy/renewable energy plan for the Canary Islands | 2,034 | 665,562 |

[9] The figures for Guadeloupe includes all the islands in the archipelago also the islands of La Desirade and Marie Galante that are mentioned separately in the table.
[10] Some of the islands in the Guadeloupe archipelago are connected by sea cable.
[11] Approximation.
[12] Approximation.
[13] Approximation

| Island | Total Percentage of Electricity Production from Renewable Energy Sources | Percentage of Electricity Production by Type of Renewable Energy Source | | Year | Island Connected to other Electricity Grid | Renewable Energy Goal/Plan/ Strategy | Area | Population |
|---|---|---|---|---|---|---|---|---|
| **Faial Island (Azores, Portugal)** | 1.1% | Hydro: | 1.1% | 1999 | | | 169.9 | 14,920 |
| **Terceira Island (Azores, Portugal)** | 0.8% | Wind: | 0.8% | 1999 | | | 399.8 | 55,706 |
| **La Gomera Island (Canary Islands, Spain)** | 0.7% | Wind: | 0.7% | 1999 | | There is a energy/renewable energy plan for the Canary Islands | 370 | 16,978 |

## Table 2: Other Islands in the Overview with Utilisation of Renewable Energy or Plans to Utilise Renewable Energy

| Island | Major Renewable Energy Technology Utilised | Installed Capacity | | Year | Renewable Energy Goal/Plan/ Strategy | Area | Population |
|---|---|---|---|---|---|---|---|
| **Barbados** | Solar water heaters | Number:<br>Percentage of households: | 31,000<br>35% | 1999 | 40% of energy to be produced from renewable energy sources by 2010 | 432 | 259,248 |
| **Cyprus** | Solar water heaters | Installed $m^2$:<br>Percentage of households:<br>Percentage of hotels: | 600,000<br>92%<br>50% | 1998 | | 9,251 | 651,800 |
| **Kiribati** | PV | | | | A US$ 3.57 million aid package to fund the installation of PV through out the Gilbert Island group from year 2000-2005 is the largest PV program in the Pacific Islands region | 746 | 75,000 |
| **St. Lucia** | None yet | | | | St. Lucia is first nation to announce its intention to transform its energy systems to a fossil-fuel-free base to the extend possible | 616 | 152,335 |
| **St Paul (USA)** | 1 x 225 kW wind turbine | | | 1999 | | | 700 |

## Table 3: Renewable Energy Share of Electricity Production in Quartiles for Investigated Islands

| Percentage of Electricity Production from Renewable Energy Sources | Percentage of Investigated Islands |
|---|---|
| 75-100% | 6% |
| 50-74% | 4% |
| 26-49% | 21% |
| 0-25% | 69% |

## Table 4: Renewable Energy Sources utilised for Electricity Production on Investigated Islands

| Renewable Eneryg Source Utilised for Electricity Production | Percentage of Investigated Islands |
|---|---|
| Biomass | 9.2% |
| Geothermal | 4.6% |
| Hydro | 27.7% |
| PV | 1.5% |
| Solid Waste | 1.5% |
| Wind power | 55.4% |

## Table 5: Location of Investigated Islands with Utilisation of Renewable Energy

| Ocean/Sea | Percentage of Investigated Islands |
|---|---|
| North Atlantic Ocean | 43.1% |
| South Atlantic Ocean | 3.9% |
| Baltic Sea | 5.9% |
| Mediterranean Sea | 3.9% |
| Indian Ocean | 3.9% |
| North Pacific Ocean | 11.8% |
| South Pacific Ocean | 13.7% |
| Caribbean Sea | 13.7% |

## Table 6: Sovereignty Status for Investigated Islands

| | |
|---|---|
| Sovereign | 23% |
| Non-sovereign | 77% |

# Azores (Portugal)

## General Information

**Population:** 260,000 (1995)

**Area (km$^2$):** 2,247

Azores is an archipelago in the Atlantic Ocean, located about 1,300 km west of Portugal. Azores is an autonomous region in Portugal.

The Azores includes nine major islands in three scattered groups: the eastern group, which includes the major islands São Miguel and Santa Maria, and the Formigas islets; the central group, which includes Faial, Pico, São Jorge, Terceira, and Graciosa; and the north-western group, which includes Flores and Corvo.

Below are specified population (for 1991) and size for the islands that will be mentioned below:

| Island | Population | Area (km$^2$) |
|---|---|---|
| Santa Maria | 5,922 | 97.1 |
| Sao Miguel | 125, 915 | 746.8 |
| Terceria | 55, 706 | 399.8 |
| Graciosa | 5,189 | 60.9 |
| Sao Jorge | 10,219 | 245.6 |
| Faial | 14,920 | 169.9 |
| Flores | 4,329 | 141.7 |

## Introduction

Electricidade dos Açores (EDA) is responsible for the production and distribution on the Azores islands – 9 electrically isolated islands. EDA is very much aware of the importance of renewable energy, not only for environmental reasons, but also to reduce the diesel/fuel-oil dependency for electricity production.

## Electricity Demand

Electricity Demand on the Azores by Sector in 1999:

| Sector | Percentage of Total Consumption |
|---|---|
| Domestic | 38.2% |
| Commerce/Services | 28% |
| Public Services | 9.5% |
| Industry | 19.5% |
| Public Lightning | 4.8% |

Source: Viveiros, 2000

## Electricity Capacity

Electricity Capacity on Santa Maria Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 3,620 kW | 93% |
| Wind | 270 kW | 7% |

Source: Viveiros, 2000

Electricity Capacity on Sao Miguel Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 51,584 kW | 70.6% |
| Geothermal | 16,000 kW | 21.9% |
| Hydropower | 5,478 kW | 7.5% |
| Renewables Total | 21,478 kW | 29.4% |

Source: Viveiros, 2000

Electricity Capacity on Terceira Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 33,470 kW | 94.4% |
| Hydro | 1,996 kW | 5.6% |

Source: Viveiros, 2000

Electricity Capacity on Graciosa Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 2,210 kW | 91.3% |
| Wind | 210 kW | 8.7% |

Source: Viveiros, 2000

Electricity Capacity on Sao Jorge Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 5,258 kW | 90.2% |
| Wind | 570 kW | 9.8% |

Source: Viveiros, 20001

Electricity Capacity on Faial Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 12,000 kW | 94.9% |
| Hydro | 640 kW | 5.1% |

Source: Viveiros, 2000

Electricity Capacity on Flores Island by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 2,106 kW | 58.7% |
| Hydro | 1,480 kW | 41.3% |

Source: Viveiros, 2000

## Electricity Production

Electricity Production on the Azores by Source in 1999:

| Source | Percentage of Total Electricity Production |
|---|---|
| Thermal Plants | 78.5% |
| Geothermal | 16.4% |
| Hydro | 4.6% |
| Wind | 0.5% |
| Renewables Total | 21.5% |

Source: Viveiros, 2000

Electricity Production on Santa Maria Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 13,968.9 | 97% |
| Wind Power | 420.8 | 3% |

Source: http://www.eda.pt/EDA/smaria.htm

Electricity Production on Sao Miguel Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 162, 904.8 | 62.4% |
| Hydropower | 18,149.2 | 7% |
| Geothermal | 79, 994.7 | 30.6% |
| Renewables Total | 98143,9 | 37.6% |

Source: http://www.eda.pt/EDA/smiguel.htm

Electricity Production on Terceira Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 116,738.3 | 99.2% |
| Wind Power | 942.9 | 0.8% |

Source: http://www.eda.pt/EDA/terceira.htm

Electricity Production on Graciosa Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 7,193.7 | 93.1% |
| Wind Power | 532.7 | 6.9% |

Source: http://www.eda.pt/EDA/graciosa.htm

Electricity Production on Sao Jorge Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 14 ,955.8 | 89.7% |
| Wind Power | 1,710.7 | 10.3% |

Source: http://www.eda.pt/EDA/sjorge.htm

Electricity Production on Faial Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 35,244.2 | 98.9% |
| Hydropower | 385.9 | 1.1% |

Source: http://www.eda.pt/EDA/faial.htm

Electricity Production on Flores Island by Source in 1999:

| Source | Electricity Production in MWh | Percentage of Total Electricity Production |
|---|---|---|
| Thermal Plants | 4 ,279.7 | 57.4% |
| Hydropower | 3 ,177.9 | 42.6% |

Source: http://www.eda.pt/EDA/flores.htm

## Geothermal

The geothermal investments, made primarily on the island of S. Miguel, can be considered successful.

The first experimental power station in Pico Vermelho, with one 3.75 MWA generator, was installed in 1980 and connected to one well, with a peak power production of 800 kW.

The experimental power station led the way to the power station of Ribeira Grande, with 4 generators of 16.25 MWA connected to 4 wells - two 3.125 MWA installed in 1994 and two 5 MWA installed in 1998.

The geothermal power stations, using steam and combined cycle turbines as prime movers, and synchronous alternators, have been used as base load on Sao Miguel, producing at maximum power available - always at a fixed level, thus not creating electrical disturbances on the network.

## Wind power

Presently there are 3 wind farms on the Azores – on Santa Maria, S. Jorge and Graciosa.

Wind Turbines on Santa Maria:

| Size | Number of Turbines |
|---|---|
| 30 kW | 9 |

Source: Viveiros, 2000

Wind Turbines on Sao Jorge:

| Size | Number of Turbines |
|---|---|
| 105 kW | 4 |
| 150 kW | 1 |

Source: Viveiros, 2000

Wind Turbines on Graciosa:

| Size | Number of Turbines |
|---|---|
| 30 kW | 9 |

Source: Viveiros, 2000

## Renewable Energy Potential

Potential for Development of Renewable Energy on the Azores:

| Renewable Energy Source | Potential |
|---|---|
| Waves | High |
| Tidal | Low |
| Biomass | Medium |
| Geothermal | High |
| Hydro | High |
| PV | Medium |
| Solar Thermal | Medium |
| Waste to Energy | Medium |
| Wind | High |

Source: CEEETA, 1997b

Regarding electricity production geothermal and wind power are the major renewable alternatives to the fuel-oil and diesel-oil power, considering the insufficient hydro resources on the islands, and the increasing utilisation of water for direct consumption.

Wind:

The Azores islands are having good wind resources, with annual mean speeds between 8 and 10 m/s and have experienced good results from the current wind farms. Therefore wind power are considered an important role in the future investments in renewable energy – either by extension of the existing three wind farms or of the installation of new wind farms.

Hydro:

With respect to the hydropower stations, some automation and upgrading are expected, to reduce the operating costs. Investments in new hydropower stations have been considered.

Geothermal:

Further investments in geothermal power have also been considered, mainly on the islands of S. Miguel, Terceira, Pico and Faial, where there are known resources.

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## References

Homepage of Electricidade dos Açores (www.eda.pt)

Viveiros, 2000

# Canary Islands (Spain)

## General Information

**Population:** 1,630,015 (1998)

**Area (km$^2$):** 7,447

The Canary Islands are a group of islands situated in the North Atlantic Ocean, off the north-western coast of Africa. The islands are an autonomous region in Spain. The seven inhabited islands are Grand Canaria, Lanzarote, Fuerteventura, Tenerife, La Palma, La Gomera, and El Hierro.

Below are specified population and size for the seven islands in the Canary Islands:

| Island | Population[1] | Area (km$^2$) |
|---|---|---|
| Grand Canaria | 714,139 | 1,560 |
| Lanzarote | 77,233 | 846 |
| Fuerteventura | 41,629 | 1,660 |
| Tenerife | 665,562 | 2,034 |
| La Palma | 81,521 | 708 |
| La Gomera | 16,978 | 370 |
| El Hierro | 8,338 | 269 |

## Introduction

The Canary Islands consist of six independent power systems whose main characteristics are their very small size and the long distance from the main supply centres. Moreover, because the non-existence of conventional energy sources in the islands, the energy dependency is nearly absolute. The Canary Islands have not yet implemented renewable energy on a large scale, but the energy plan 1996-2002 is focusing on wind, solid waste and solar energy as viable resources. The islands are situated in a privileged situation for using renewable energy – especially solar and wind resources.

## Electricity Capacity

Installed Electricity Capacity for the Canary Islands by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 1,642.147MW | 95.27% |
| Hydropower | 0.8MW | 0.046% |
| Wind Power | 80.15MW | 4.65% |
| PV | 0.570MW | 0.033% |
| Renewables Total | 1,723.667MW | 4.73% |

Source: www.cistia.es/dgie/anu00_elec.htm

## Electricity Production

Electricity Production for the Canary Islands by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 6,094,395 GWh | 96.44% |
| Hydropower | 1,773 GWh | 0.028% |
| Wind Power | 223,013 GWh | 3.53% |
| PV | 0.093 GWh | 0% |
| Renewables Total | 224,786.093 GWh | 3.56% |

Source: www.cistia.es/dgie/anu00_elec.htm

Electricity Production on Grand Canaria Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 2,600 GWh | 96% |
| Wind Power | 109.71 GWh | 4% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

Electricity Production on Lanzarote Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 548.187 GWh | 96.8% |
| Wind Power | 17.933 GWh | 3.2% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

Electricity Production on Fuertenventura Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 299.313 GWh | 91.4% |
| Wind Power | 28.037 GWh | 8.6% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

[1] For year 1996

Electricity Production on La Gomera Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 45.8856 GWh | 99.3% |
| Wind Power | 0.3144 GWh | 0.7% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

Electricity Production on El Hierro Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 22.21492 GWh | 95.8% |
| Wind Power | 0.96508 GWh | 4.2% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

Electricity Production on Tenerife Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 2,414.44488222 GWh | 98.42% |
| Wind Power | 38.139157 GWh | 1.55% |
| Hydro[2] | 0.5459608 GWh | 0.02% |
| Renewables Total | 38.6851178 GWh | 1.57% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

Electricity Production on La Palma Island by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 182.9257608 GWh | 94.5% |
| Wind Power | 9.3576 GWh | 4.8% |
| Hydro[3] | 1.2266392 GWh | 0.7% |
| Renewables Total | 10.5842392 | 5.5% |

Source: www.cistia.es/dgie/anu00_elec.htm and www.cistia.es/dgie/anu00_renov.htm

### Solar Thermal Energy

Thermal solar energy is one of the most important renewable energy sources in the Canary Islands.

There were 53,992 m$^2$ solar thermal installations by 1999.

There is a factory to produce solar panels on Tenerife Island. The factory is owned by Energia Eólica y Solar Española (E.S.E.). ESE has 70% of the market. The most important foreign manufactures are from Israel – AMCOR and CROMEGAN.

### Renewable Energy Potential

Potential for Development of Renewable Energy on the Canary Islands:

| Renewable Energy Source | Potential |
|---|---|
| Waves | Medium |
| Tidal | Low |
| Biomass | Low |
| Geothermal | Low |
| Hydro | Low |
| PV | High |
| Solar Thermal | High |
| Waste to Energy | High |
| Wind | High |

Source: CEEETA, 1997b

### Energy Policy

There is an energy plan for the Canary Islands - Plan Energético de Canarias (PERCAN). The timeframe is from 1996-2002. Among other things PERCAN draws together criteria and measures for ensuring the introduction and use of renewable energy technologies.

The main objectives of PERCAN are:

► assure energy supply

► reduce vulnerability by diversifying the energy sources

► promote the rational use of energy

► reduce the energy dependency from external energy sources by promoting as much as possible the use of new energy sources

► assure a stable and reliable energy offer

► minimise energy costs in he different production sectors

► contribute to the environmental protection and conservation

Wind Energy:

Establishment of high power wind farms in areas, which are most suitable. The most suitable areas should be based on environmental impact study in co-operation with the Directorate General of Territorial Policy. The selection of the best suitable areas should also be based on a stability study of the grid in co-operation with UNELCO. In the areas with no connection to the grid, studies

[2] Approximation
[3] Approximation

should be carried out regarding the possibilities of using wind turbines as water pumps. These studies should be carried out in co-operation with the Directorate General of Public Works, Housing and Water. Finally, demonstration projects should be planned.

Mini-hydro and Geothermal Energy:

A study should be carried out in co-operation with the Directorate General of Public Works, Housing and Water about the possibilities and potentials of mini-hydro and geothermal exploration.

Solid Waste Energy:

Solid waste as a energy resource should be promoted among the companies who are handling the waste and disposal of waste. Besides that, PERCAN should participate in the framework of future planning concerning an efficient use of solid waste.

Thermal Solar Energy:

The installation of 36,000 $m^2$ of solar panels in a period of 6 years. In order to achieve this objective the PERCAN includes the following measures:

► set up an operator agent to start the programme

► a system of financing installations

► officially approved collectors, installations made by an accredited enterprise, maintenance guarantee etc.

► promotion actions – demonstrations in public establishments, promotion in the hotel sector, press and radio dissemination, particular incentives to local entities, private potential user etc.

PV:

Realisation of studies, the purpose of which is to determine the potential for PV in rural areas. These studies should mainly be focussed on applications isolated from the grid.

Biomass Energy:

Feasibility studies, experiences, pilot and demonstration projects should be carried out concerning the use of energy crops in the production of, for example, bio-fuels as well as utilisation of forest and farming waste.

**Full Supply for El Hierro Island by means of Renewable Energies**

El Hierro is the smallest and most western of the Canary Islands. It has a population around 8,000 and the island is approximately 270 $km^2$.

Background:

The island Government of El Hierro adopted the Sustainable Development Programme in November 1999. The objective of the programme is to use a broad series of projects - in accordance with the guidelines laid down by the Rio Summit - to strike a balance between human development and conservation of the nature on the island.

The programme covers areas like agriculture, transport, tourism, industry, energy, water, agriculture, livestock etc. Thus, clean and sustainable energy production on the island is a fundamental part of the broad strategy.

Objective:

The objective is 100% supply of electricity production on El Hierro from renewable energy sources.

Existing Power System:

Electricity is produced at a conventional power system with a rated capacity of 8,280 kW and two wind turbines with a rated capacity of 280 kW.

In 1999 wind power produced 4.2% of the generated electricity.

Average electricity consumption on the island is around 2,000 kW, with peaks in the summer when there are more visitors on the island of up to 4,000 kW.

Proposed Power System:

The unpredictable nature of wind, fluctuations in the wind, periods of calm wind and the need for stability in an electricity grid subject to variable demand makes it technically difficult to match energy demand and supply with wind power if it does not have a storage system.

Therefore is it proposed to make a system with the following components:

► a 10 MW wind farm consisting of 20 turbines

► a water pumping system

► a water storage reservoir sited at an altitude of 700m and with a total capacity of 500,000 $m^3$. The water reserves would cover an 8 day period of calm winds

► a return loop and turbine connected to an electric generator

All these elements would be necessary if the water used comes from the sea.

If fresh water is chosen for the system, the following components would also be necessary:

► a water reservoir down at sea level, the same size as the upper one

► a sea water desalination plant

<u>How the Proposed System would Work:</u>

The wind turbines would pump water up from sea level, or from the sea, to the reservoir at 700 m, where a potential energy reservoir would be created. The water would be piped down from the reservoir to a turbine and generator, and the flow would be regulated according to energy demand from the grid.

If fresh water were used, a desalination plant would be necessary. The advantages of using fresh water would be a reduction in the level of corrosion in system components, and the possibility of using the water produced for domestic use and irrigation.

**Contact Information**

| | |
|---|---|
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**References**

CEETA, 1997b

Gonzalez, 1998

Gulias, 1999

Homepage of the Directorate General for Industry and Energy, Government of the Canary Islands (http://www.cistia.es/dgie/)

Morales, 1999

Torres, 1998

# Cape Verde

## General Information

**Population:** 411,487 (2000 estimate)

**Area (km$^2$):** 4,033

The archipelago of Cape Verde is situated in the North Atlantic, 445 km off the western coast of Africa.

The archipelago consists of ten islands and five islets, which are divided into windward and leeward groups. The windward, or Barlavento, group on the north includes Santo Antão, São Vicente, São Nicolau, Santa Luzia, Sal, and Boa Vista; the leeward, or Sotavento, group on the south includes São Tiago, Brava, Fogo, and Maio.

Below are mentioned population and area for the islands that will be specified regarding wind power in this section:

| Island | Population[1] | Area (km$^2$) |
|---|---|---|
| Sal | 10,168 | 298 |
| Sao Vicente | 63,040 | 246 |
| Sao Tiago | 210,932 | 992 |

## Introduction

The energy sector in Cape Verde is characterised by a high dependency on imported oil products. Due to its geographical location, the country cannot access the main energy networks and is forced to import oil derivatives. In 1996, the import of oil products covered more than 70% of all available energy sources. A great amount of the imported fuel is re-exported to supply marine and air transportation. Another source of energy for Cape Verde is biomass, particularly in the rural areas. Biomass represents 37.4% of the total consumption of energy and is generally used to cook. Kerosene is also largely used for cooking in rural areas while butane gas is preferred in urban areas.

## The Power Sector

The electricity sector is quite decentralised even though the state owned power utility Electra controls the production and distribution in the main population centres. There are 40 electric grids in the entire country and only 4 belong to Electra – the rest is administered by municipalities. Here Town Councils are responsible for both distribution and production.

Only 43% of the population have access to the electricity network, and in the rural areas this number does not exceed 14%. The almost complete lack of power transmission networks has led to the proliferation of small power plants, aimed at fulfilling the electricity requirements of rural populations. In 1997 San Tiago had 19 power plants, Santo Anrao had 8, Boa Vista 6, Fogo 5, not to mention small household operated diesel groups (1 to 5 KVA).

## Wind Power

Cape Verde's wind energy resources from the trade-winds provides a strong north-eastern flow for most of the year. Since the early 1980s projects have documented the technical and economical feasibility of today's wind energy technology for Cape Verde.

Three Grid Connected Wind Farms:

Three wind farms with a total capacity of 2.4 MW were installed in the main power systems of Cape Verde in 1994. The turbines are eight 300 kW Nordtank turbines.

Operation Statistics for Wind Farms at Sal (Sal Island), Mindelo (Sao Vicente Island) and Praia (Sao Tiago Island) Power Systems for 1995-1997:

| | Sal (Sal Island) | Mindelo (Sao Vicente Island) | Praia (Sao Tiago Island) |
|---|---|---|---|
| Available Diesel Capacity (MW) | 4 | 11 | 12 |
| Diesel Fuel Type | Gas oil | Heavy fuel | Gas oil |
| Installed Wind Turbine Capacity (kW) | 600 | 900 | 900 |
| Avg. Wind Speed at Hubheight (m/s) | 7.4 | 10.4 | 7.8 |
| Annual Wind Energy Production (MWh) | 1440 | 4390 | 2500 |
| Annual Power System Load (MWh) | 10120 | 32800 | 39870 |
| Avg. Wind Energy Production (%) | 14 | 14 | 6.3 |
| Average Wind Turbine Capacity Factor (%) | 27 | 56 | 31 |
| Annual Diesel Fuel Savings (t) | 340 | 970 | 615 |

Source: Hansen, 1998

[1] 2000 estimate.

The wind farms have established the technical viability of this technology, and built technical capability in Electra for system operation and monitoring. The projects have demonstrated that there is considerable additional potential for cost reduction in the wind generation and scope for substantially increased penetration into the networks.

The penetration levels have been achieved without any special wind farm controller expect for the standard wind turbine controllers in each machine. Wind farm control actions have been manual, exercised by the diesel power plant operators.

The total technical availability has been high (92-98%).

The turbines were jointly financed by the Capeverdean government and Denmark's development agency Danida.

**Extension of Existing Wind Farms**

Modelling has shown that a further expansion of the three wind farms installed in the main power systems of Cape Verde is technically possible and economically attractive.

The World Bank has approved a US$ 22.2 million in funding to Cape Verde for the Cape Verde Energy and Water Sector and Development Project.

The project includes US$ 3.7 million for wind power development. This component would finance the extension of the existing grid connected wind farms on Sal, Sao Vicente, and Sao Tiago with a total increase of up to 7.8 MW. The planned 7.8 MW will almost triple the installed wind capacity in Cape Verde to nearly 11 MW. The new projects could lead to a penetration of up to 1/3 in the island's grids.

The wind farms would be constructed after the privatisation of Electra.

**Contact Information**


| | |
|---|---|
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**References**


CEEETA, 1997a

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Hansen, 1998

Information provided by Instituto Superior Técnico, Portugal

Windpower Monthly, 1999

Worldbank, 1999

# Faeroe Islands (Denmark)

## General Information

**Population:** 48,000 (1994 estimate)

**Area (km$^2$):** 1,400

The Faeroe Islands are located in the Atlantic Ocean, almost midway between Norway, Iceland and Scotland. The Faeroe Islands are part of the kingdom of Denmark. There are 18 main islands separated by narrow sounds and fiords and a few small, uninhabited islands.

## The Energy Sector – Introduction

Household heating and the fishing fleet consume the major share of gas and diesel oil, while most of the fuel oil is used to produce electricity.

The dominant form of space heating is traditional oil stoves. Electric heating is scarcely used at all, due to the relatively high power prices. Surplus heat from the thermal plants is not utilised, with the exception of heating at the power stations themselves. District heating is available in Thorshavn to only a limited area. The area is supplied with surplus heat from the local waste incineration system, and supplies approximately 250 houses.

There have been discussions on expanding the district heating system to a far larger part of Thorshavn during recent years. But as this is not financially viable under the current circumstances, it would not be possible for the district heating company to carry out this project alone at present.

Electricity consumption fell from 1989 to 1995, but has since risen slowly. The fluctuation in consumption is mainly due to the economic decline and the fall in population until 1995, followed by growth in both the economy and the population.

Slightly less than 90% of the inhabitants are supplied by an integrated electricity net, while Suderoe Island, with just under 5,000 residents, and five small islands with populations totalling approximately 150, all have their own island power stations.
A very large percentage of electricity is produced at hydroelectric plants as can be seen in the table below.

## Electricity Capacity

Installed Capacity by Source, in 2000: [1]

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 53.4MW | 62.9% |
| Hydropower | 31.4MW | 37% |
| Wind | 0.15MW | 0.1% |

Source: The Government of the Faeroe Islands, 2000

## Electricity Production

Electricity Production by Source in 1999: [2]

| Source | Percentage of Total Production |
|---|---|
| Thermal Plants | 64.9% |
| Hydro Power | 34.9% |
| Wind power | 0.2% |
| Renewables Total | 35.1% |

Source: The Government of the Faeroe Islands, 2000

Minimum load on the power net is approximately 14 MW in the main area, and approximately 1.5 MW on Suderoe Island.

## Hydropower

The power company, SEV, is currently expanding with hydroelectric power. When the present expansion phase at Eysturoy Island is completed in the spring of year 2000, the hydroelectric share of total power production will be approximately 50%. In addition to this, the power company has specific plans to continue expansion of hydroelectric power on Eystruroy Islands with what will correspond to approximately 19 GWh annually.

It is expected that hydroelectricity will be expanded during the coming years.

## Wind Power

Since 1993, the electricity company, SEV, has had a trial wind turbine in operation. The turbine has been reinforced to enable it to withstand the high wind speeds. Operational experience was so good, that it was decided in 1998 to purchase an additional wind turbine. The extreme wind conditions mean that suitable turbines are more expensive than standard models, but they are also able to produce more electricity per unit in comparison to wind turbines in, e.g., Denmark.

[1] This includes the islands that are part of the integrated electricity net and Suderoe Island (on Suderoe Island there is installed 7.4MW thermal and 3MW hydropower).
[2] This includes the islands that are part of the integrated electricity net and Suderoe Island.

## Energy Policy

There is no general energy plan for the Faeroe Islands.

## Contact Information


| | |
|---|---|
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## References


Information provided by the Government of the Faeroe Islands

Klima 2012, 2000

# Madeira (Portugal)

## General Information

**Population:** 260,000 (1998)

**Area ($km^2$):** 797

Madeira Islands is an archipelago in the Atlantic Ocean, located about 1,100 km south-west of Portugal. Madeira Islands are an autonomous region in Portugal.

The Madeiras consist of two inhabited islands, Madeira and Porto Santo, and two uninhabited island groups, the Desertas and the Selvagens.

| Island | Size | Population |
|---|---|---|
| Madeira Island | 765 | 248,339 |
| Porto Santo Island | 42 | 5,000 |

## Introduction

Due to its geographic location and because it has no fossil energy resources, the Region of Madeira is heavily dependent on outside resources. Furthermore, because of the relatively small dimension of the energy system, the main energy alternatives to petroleum, such as nuclear energy, gas and coal, are not feasible. Local resources such as biomass (firewood), hydro, wind and solar represented 8% of the primary energy sources in 1998.

## Electricity Demand

Electricity Demand for Madeira Island by Sector in 1998:

| Sector | Demand in GWh | Percentage of Total Demand |
|---|---|---|
| Industry | 50.13 | 11% |
| Public Services | 39.83 | 9% |
| Public Lightning | 36.87 | 8% |
| Commerce and Services | 166.14 | 37% |
| Residential and Agricultural | 162.6 | 35% |

Source: AREAM, 2000

Electricity Demand for Porto Santo Island by Sector in 1998:

| Sector | Demand in GWh | Percentage of Total Demand |
|---|---|---|
| Industry | 2.26 | 16% |
| Public Services | 3.06 | 21% |
| Public Lightning | 1.09 | 8% |
| Commerce and Services | 3.47 | 24% |
| Residential and Agricultural | 4.47 | 31% |

Source: AREAM, 2000

The growth of demand for electricity in the 1990's was very high, mainly due to the residential and tertiary sectors. The electricity demand increased from 261.30 GWh in 1990 to 467.92 GWh in 1998. This is an increase of 75%, which corresponds to an average growth of 7.5% per year.

## Primary Energy Sources

Primary Energy Sources for the Madeira Islands by Source in 1998:

| Source | Percentage of Primary Energy Sources |
|---|---|
| Oil | 92% |
| Renewables | 8% |

Source: AREAM, 2000

## Electricity Capacity

Installed Electricity Capacity on Madeira Island by Source in 1998:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 125,800 kW | 69.6% |
| Hydropower | 49,550 kW | 27.4% |
| Wind Power | 5,340 kW | 3% |
| Renewables Total | 54,890 kW | 30.4% |

Source: http://www.madinfo.pt/eem/rel05.html

Installed Electricity Capacity on Porto Santo Island by Source in 1998:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Diesel | 13,820 kW | 96.8% |
| Wind | 450 kW | 3.2% |

Source: http://www.madinfo.pt/eem/rel05.html

Empresa de Electricidade (EEM) is a public company and is responsible for the production, transportation and distribution of electricity for both islands of the Autonomous Region of Madeira.

**Electricity Production**

Electricity Production for Madeira Island by Source in 1998:

| Source | Generated Electricity | Percentage of Total Production |
|---|---|---|
| Diesel | 426.96 GWh | 82.6% |
| Hydro | 78.32 GWh | 15.2% |
| Wind | 11.67 GWh | 2.2% |
| Renewables Total | 89.99 GWh | 17.4% |

Source: http://www.madinfo.pt/eem/rel05.html

Electricity Production for Porto Santo Island by Source in 1998:

| Source | Generated Electricity | Percentage of Total Production |
|---|---|---|
| Diesel | 17.546 GWh | 94.5% |
| Wind | 1.018 GWh | 5.5% |

Source: http://www.madinfo.pt/eem/rel05.html

**Hydropower**

The hydro-electrical power plants on Madeira Island works on a "run-river" mode, with a small storage capacity - just for a few hours in some cases. In 1998, 15.2% of the electricity produced was from hydropower, which meant, in terms of energy, a production of 6,736 toe. Thus, 16,003 tonnes of fuel oil were saved.

**Wind Power**

Wind energy on Madeira is attractive, due to the availability of good wind conditions.

The wind parks on Madeira Island are private and they sell the energy to the public electricity grid in accordance with the Portuguese legislation for independent energy production. The actual legislation requires the public grid to buy the energy produced by independent electricity producers and guarantees a minimum price, based on an established formula.

Madeira Island:

The total installed capacity is 5,340 kW.

Wind Turbines on Madeira Island in 1999:

| Size of Turbine | Number of Turbines |
|---|---|
| 130 kW | 3 |
| 150 kW | 33 |

Source: AREAM, 2000

The capacity will increase in the near future with the installation of 5 x 660 kW wind turbines.

Porto Santo Island:

There are 2 x 225 kW turbines on the island. The capacity will soon increase with 1 x 660 kW wind turbine.

**Solar Thermal**

The region has favourable conditions for utilising thermal solar energy, but the potential have not yet been exploited.

Hundreds of solar heating systems are scattered around the island, representing more than 3,500 $m^2$ (in 1991).

There has been a crisis in the demand for solar thermal systems as a result of:

► a relatively high investment, especially for small installations, in which the payback is spread out over a very long term

► lack of investment security due to the poor quality of some collectors, poorly designed size of installations, and poor workmanship in setting up the installations

► the low price of conventional energy sources

**PV**

In terms of PV, the region has expertise in this field. In 1983, the first PV installation in Portugal was set up on the Selvgem Grande island (a nature reserve) and is still in full operation. Likewise, the majority of the Navy lighthouses have PV systems.

Even though there have been important steps made to use PV in signalling systems and isolated houses, PV has not a made a significant contribution to the energy balance.

**Main Barriers**

The main obstacle for the development of renewable energy resources for electricity production in the Madeira Islands is the integration of the energy produced into the grid. The small dimension of the energy system creates a limitation in the capacity to receive – in acceptable conditions – electricity produced by wind energy. The high fluctuation in the electricity demand throughout the day set limitations on the electricity reception from e.g. wind turbines.

On the other hand, it is common amongst electricity producers who use conventional energy resources, that they sometimes have difficulties in accepting new initiatives. These difficulties often appear as fear in relation to the introduction of new technologies, the behaviour of which is sometimes unknown.

In connection with solar energy, the main barrier is the weak acceptance due to the high costs and sometimes poor quality of equipment and installation.

**Renewable Energy Potential**

The growth of the power supply capacity during the next decade will primarily be based on thermal production. A large development in renewable energies in not forecasted in the near future, namely due to the limitations and constraints on increasing the penetration from renewables in electricity production. Furthermore, the most suitable energy resources are all ready being exploited.

Potential for Development of Renewable Energy on the Madeira Islands:

| Renewable Energy Source | Potential |
|---|---|
| Waves | Medium |
| Tidal | Low |
| Biomass | High |
| Geothermal | Low |
| Hydro | High |
| PV | Medium |
| Solar Thermal | High |
| Waste to Energy | High |
| Wind | High |

Source: CEEETA, 1997b

Hydro:

Today, Madeira Island does not have the conditions required for constructing new high-power capacity hydroelectric power plants. The steep terrain, lack of available land and the porosity of the soil are unfavourable conditions for storing large amounts of water. What is still possible and feasible, however, is the investment in micro-hydroelectric plants with power capacities under 1 MW.

Wind and Solar:

Both wind and solar resources represent a high potential and have a huge development potential in the future. For instance, wind energy can be applied for seawater desalination and pumping.

Solid Waste:

The exploration of solid waste as a resource is being considered in an incineration waste treat plant.

Wave:

The Autonomous Region of Madeira is located in an area of the North Atlantic where the energy potential of the sea waves reaches a level which may be of interest in terms of energy production. Considering the high investment costs and deficiencies in existing technologies its potential is not considered to be economically feasible at present time.

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**References**

AREAM, 2000a

AREAM, 2000b

CEETA, 1997b

Fernandes et al, 2000

Homepage of Electricidade da Madeira (EEM) (http://www.madinfo.pt/eem)

Mendes, 1998

Oliveira, 1999

# Pellworm (Germany)

## General Information

**Population:** 900

**Area (km$^2$):** 37

## Electricity Capacity

Installed Electricity Capacity by Source in 1997:

| Source | Installed Capacity |
|---|---|
| Wind Power | 5,900 kW |
| PV | 600 kW |

Source: http://www.pellworm-energy.org/ and

The island is connected to the mainland electricity net in Germany via sea cables.

## Electricity Production

Electricity Production by Source in 1998:

| Source | Electricity Production | Percentage of Electricity Production |
|---|---|---|
| Import from the Mainland by Cable | 7,940 MWh | 34.07% |
| Wind Power | 15,136 MWh | 64.96% |
| PV | 225 MWh | 0.97% |
| Renewables Total | 15,361 MWh | 65.93% |

Source: http://www.pellworm-energy.org/

## Renewable Energy Plan

In 1997 a renewable energy plan for Pellworm was elaborated. The title of the plan is Energy Supply on the Basis of Renewable Energy Sources Using the Example of the North Sea Island Pellworm – A Local Development Plan.

The goal of the development plan was to present model concepts for energy supply based on renewable energies and to access a broad spectrum of applications. Special emphasis was given to wind power and biomass and to ways of storing energy.

The overall objective for the renewable energy plan is a $CO_2$-free island.

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E-mail: info@pellworm-energy.org
Internet: http://www.pellworm-energy.org

## References

Forum für Zukunftsenergien, 1997

Homepage of Pellworm Energy (http://pellworm-energy.org)

Homepage of SCHLESWAG (http://www.schleswag.de/)

# St. Pierre and Miquelon (France)

## General Information

**Population:** 6,300

**Area (km$^2$):** 242

Saint-Pierre and Miquelon is a territory of France situated in the North Atlantic Ocean south of the coast of Newfoundland, Canada. The main islands are Saint-Pierre, Miquelon, and Langladem (the latter two connected by the low, sandy Isthmus of Langlade).

## Installed Electricity Capacity

26,8 MW diesel plants installed (1999).

## Electricity Production

38 GWh delivered to the grid (1999).

## Wind Power

The archipelago is a windy place and is seeking to exploit this as part of three projects: a Wind House, a Wind Farm on Miquelon and a wind farm on St. Pierre.

Wind House:

The first one is based on the "Wind House", a combination of museum and European scientific and technical centre, which will provide visitors with information and scientific explanations about the wind, how to observe it and how to exploit it.

Miquelon Wind Farm:

The project is described later in this section.

St. Pierre Wind Farm:

A 1.8 MW wind farm is planned for St. Pierre.

## Miquelon Wind Farm

Electricity Consumption on Miquelon:

The energy needs are approximately 5,750,000 kWh per year (1999/2000).

Electricity Capacity:

Installed Electricity Capacity in 2000 by Source:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 4,200 kW | 87.5% |
| Wind | 600 kW | 12.5% |

Source: Information provided by VERGNET S.A.

The Wind Farm:

The wind power station of Miquelon was initiated in 1994 and was commissioned in April 2000.

The wind resources are 8.6 m/s at 30 m above ground.

The wind farm consists of 10 x 60 kW VERGNET wind turbines (blade diameter 15 m) in connection with the diesel network of the island. It will allow, with an estimated annual production of 1,700,000 kWh to produce 30% of the electricity on the island.

The are two aspects of this project: firstly, it forms part of a general development strategy aimed at taking advantage of all the archipelago's features and resources and, secondly, it enables St. Pierre and Miquelon to act as a European technological showcase for its immediate neighbours in North America.

This wind power site will promote the technology devised by VERGNET S.A., which has developed and adapted, specifically for St. Pierre and Miquelon, a wind power generation system combined with a diesel engine. This is perfect to the circumstances of the archipelago, notably in terms of climate and available space.

As a "direct supply" system, it is very economical and is connected straight into the local distribution network, which means there is no need for costly storage of power since this is used as it is produced. Such technology is tailor-made for isolated communities.

## Contact Information


| | |
|---|---|
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| Internet: | Www.vergnet.fr |


## References


The Courier, 1999

Correspondence with VERGNET S.A.

Donizeau, 2000

Homepage of VERGNET S.A.
(www.vergnet.fr)

# Ascension Island (U.K.)

### General Information:

**Population:** 1,100

**Area ($km^2$):** 82

Ascension Island is located in the South Atlantic Ocean, 7 degrees south of the equator and midway between the African and South American continents.

Ascension Island is an overseas territory, which forms part of a single territorial grouping under the sovereignty of the British Crown.

The island is home to an U.S. Air Force satellite-tracking station.

### Electricity Production

Electricity Production by Source, in 1997:

| Source | Percentage of Total Electricity Production |
|---|---|
| Thermal Plants | 84% |
| Wind Power | 16% |

Source: Information provided Alpha Wind Energy

### U.S. Air Force Wind Farm

The first wind farm in the U.S. Department of Defence is located on Ascension Island.

Project Summary:

Installation of four wind turbines in parallel to an existing diesel and desalination plant allows the US Air Force to offset the consumption of approximately 1 million litres of diesel fuel annually at their Ascension Island Air and Space Launch support base.

Wind Speeds:

Annual average wind speeds are 7-8 m/s with a typical trade-wind distribution.

Engineering Data:

► The island has a prime power diesel plant.

► Island load is from 2.2-2.4 MW.

► Two 1,900 kW diesel generators operate in parallel with the wind farm.

► Waste engine heat desalination system.

► Wind farm supplements diesels.

Wind Farm Configuration:

The wind farm consists of 4 units of Micon M700-225/40 kW wind turbines each with 29.8 metre rotor diameters and 30 metre tower heights. Additionally an indoor switchgear was installed on the turbine site and a remote SCADA system located in the control room of the power plant.

Project Concerns:

► Site approval was required. Involving the Island Administrator early was very important

► Environmental concerns were bird strikes and electromagnetic interference. Both have proved groundless.

► High corrosion.

► Wind vs. generator penetration ratio.

Construction Challenges:

► Remote shipping – 5000 miles from port.

► Restricted shipping schedules.

► Pier restrictions.

► Limited crane availability and reach.

► Limited island access.

Project Highlights:

The island's extremely remote and isolated location posed several logistical and environmental challenges, including offloading on lighters in the open sea off the island and pre-fabricated foundation systems. Despite these challenges, the project was commissioned within budget and 6 months ahead of schedule.

Wind Farm Performance:

► Average wind power output is 370 kW.

► 41% capacity factor.

► Power production is on track.

► Micon M700-225kW working flawlessly.

► Corrosion free.

► As of March 2000, the wind turbines have operated with an average availability well above 99%.

► As of March 2000 10.5 millions kWhs have been produced since commissioning in late September of 1996.

► $NO_x$ and $CO_2$ reduced.

Lessons Learned:

► Perform resource assessment.

► Mandatory job walk essential.

► Partner with the teams.

► Performance based specifications.

► Conquer corrosion control.

► Establish maintenance contract.

► Plan and model loads.

**Contact Information**


| | |
|---|---|
| Organisation: | Idaho National Engineering and Environmental Laboratory (INEEL) |
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| Internet: | |


**References**


Seifert, 1997

Information from Alpha Wind Energy

# St. Helena (U.K.)

## General Information

**Population:** 5,564 (1988)

**Area (km$^2$):** 122

Saint Helena is located in the South Atlantic Ocean, about 1,930 km west of Africa. The island is part of the British dependency Saint Helena, which also includes Ascension Island and the island of Tristan da Cunha.

## Electricity Capacity

Installed Electricity Capacity by Source in 2000:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 2,712kW | 91.9% |
| Wind | 240kW | 8.1% |

Source: Energy Division St. Helena, 2000

The diesel power station is located at Ruperts Valley. There are five Mirrlees Engines with Brush Alternators.

## Grid

Electricity is distributed around the island at 11,000 volts. The supply to consumers is 230/240 volts A.C 50 Hz single phase and 415 volts A.C 50 Hz three phase.

## The Deadwood Plain Wind Farm

Three 80kW Lagerwey wind turbines on 18 metre towers were erected in June 1999 at Deadwood Plain. The contractors were Taylor Woodrow Construction Limited, England.

Background:

The project is part of a package of measures to safeguard the existing diesel generated suppliers, improve system efficiency and incorporate an element of renewable energy.

Feasibility Study:

A study of the feasibility of wind turbine power generation was carried out in 1994. It concluded that wind power was technically appropriate and economically and financially viable.

Wind Regime:

St. Helena has an indigenous wind regime of almost constant force and magnitude which is well suited for wind powered generation.

There was wind measurement at the Deadwood Plain between December 1991 and November 1992. The mean wind speed at 30.4 metres height for the year was 10.26 metres/second, which was scaled by a factor to produce a mean of 9.6 m/s to correspond with the predicted long-term mean.

Production:

For the first six months of operation, the wind turbines have produced 13% of the total units generated.

From December 1999 to end of March 2000, wind speeds have varied from 3.5 to 15 m/s.

The wind turbines are connected to 315 KVA Transformer, which in turn is connected to the grid 11,000 volts.

Organisation:

The wind turbines are financed with aid from the British Department for International Development.

The wind turbines are owned by the St. Helena Government.

Operation and maintenance is the responsibility of the Energy Division.

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Internet: Http://www.twc.co.uk/

**References**

Information provided by Energy Division on
St. Helena

# Aeroe (Denmark)

### General Information

**Population:** 7,600

**Area (km$^2$):** 90

Aeroe is situated in the southern part of Denmark.

### Introduction

In 1997/1998 the Danish island of Aeroe took part in a competition to become the official Danish Renewable Energy Island (REI).

Aeroe was not chosen, but continues to work towards the goal of 80-100% supply of renewable energy plus energy savings during the period from 1998 to 2008.

### Electricity Production

Electricity Production by Source in 1999:

| Source | Percentage of Total Production |
|---|---|
| Import by Cables | 87.3% |
| Wind power | 12.7% |

Source: Aeroe Energy and Environmental Office, 2000

### Wind Turbines

All the 22 wind turbines are connected to the grid and are selling the production to the local utility company. The total sale in 1999 was 4,550 MWh.

Most of the turbines are smaller ones erected at the beginning of the ´80es. Wind conditions are very good, and production has been very profitable for the owners. Running and maintenance of the turbines has generally been without problems.

The wind turbines are:

► 11 x 55 kW wind park owned in a partnership between private investors (households) and businesses. Shares can be sold and bought among the islanders. Local craftsmen have a part-time job maintaining the turbines. A board among the owners is responsible for the operation.

► 1 x 75 kW and 2 x 200 kW owned by Aeroeskoebing District Heating.

► 1 x 400 kW owned by SH an electricity company on the mainland.

7 turbines from 55 kW to 100 kW owned by small partnerships.

### The Energy Plan for 1998-2008

Objectives:

The overall objective is to convert the energy supply on Aeroe to 80-100% renewable energy over a period of 10 years from 1998 to 2008.

The immediate objectives are:

► Reduction of CO2 and other pollutants generated by production of electricity and heat, and through a sustainable local production of energy

► Maintain, if not increase the competence with regard to energy in the local business community

► Through a certain degree of self-sufficiency creating new jobs

► To “green” existing jobs within the energy supply sector

► To create a monetary abundance as the payment for the energy supply remains in circulation on the island

► To establish a supply of energy which is at the forefront of the development

► To contribute in maintaining/increasing the population on the island by participating in the development of “the green island”

► To maintain and hopefully increase the number of energy related tourists

Technical goals:

► Wind Power:

Erection of 10-12 MW wind power

► District heating:

| Town | Activity |
|---|---|
| Marstal | Thermal solar heating, 9,000 m$^2$ are established<br><br>Conversion to renewable energy for the remaining production is being investigated. For instance thermal solar heating: 75,000 m$^3$ seasonal storage and a total of 40,000 m$^2$ solar heating |

| | |
|---|---|
| | or 4 MW of biomass |
| Aeroeskoebing | Biomass: extension from the current 1.6MW to 2.5MW<br><br>Thermal solar heating: 5,000 $m^2$ are established |
| Rise | Biomass: 600 kW<br><br>Thermal solar heating: 4,000 $m^2$ and seasonal storage |
| Soeby | Biomass: 2 MW<br><br>Thermal solar heating: 2,250 $m^2$ |

► Individual Means of Heating:

Solar collectors and biomass boilers for approximately 1,500 detached properties.

► Energy Savings

**The Electricity Sector**

Aeroe Elforsyning A.m.b.a is main grid operator.

The electricity consumption is on an average 36 million kWh per year.

After changes in consumer-habits, streamlining of the apparatus, use of electrical vehicles and by increasing the use of heat pumps, it is expected that the consumption can be reduced to 31 million kWh annually during a period of 10 years.

The planning for erection of new wind turbines has been initiated by the Renewable Energy Organisation of Aeroe. It is the plan to cover the electricity consumption completely by renewable energy on an annually basis. At the moment the work is concentrated on erecting 5-6 new wind turbines each of 2 MW. The turbines are expected to produce 29-34 million kWh.

More than half of the existing turbines will be demolished with the erection of the new turbines, the rest will be phased out.

The municipality in Aeroeskoebing has approved the project. Other authority proceedings have been initiated.

In addition there is the possibility of CHP at Marstal District Heating, plus demonstration projects with solar cells and further savings.

Responsible for the erection of the new windturbines: "Aeroe Vindmøllelaug" (entrepreneurs).

**Marstal District Heating Company A.m.b.a**

In 1998 the production was 27,216 MWh. Thermal solar heating covers 13% of the production. Today the plant is the world’s largest thermal solar heating system supplying district heating. It enjoys widespread attention, and has been invited to EXPO 2000 as one of the 5 most interesting developments at the moment.

In connection with the plant is a test site, an earth pipe storage complete with heat pump. The remaining production takes place in waste oil boilers. The company is exploring the possibilities of exchanging the oil with:

1) CHP from a biomass boiler

2) heat production from a biomass boiler or

3) extension of the thermal solar heating plant in conjunction with 1) or 2).

Marstal District Heating extended its pipeline to the village Graesvaenge in 1999. There is a plan ready for an extension to the village Ommel. The extension will commence when the necessary finances are available.

**Aeroeskoebing District Heating Company A.m.b.a**

A yearly production of 13,000 MWh. Aeroeskoebing District Heating covers 18% of its sale through thermal solar heating. 75% is derived from a straw boiler and the remaining 7% is obtained from oil boilers. In the year 2000 it is planned to install a wood pellet boiler to replace the oil.

**Rise District Heating Company A.m.b.a**

Rise District Heating is a "bare field project" starting up. The initiative originates from Aeroeskoebing Municipality and Renewable Energy Organisation of Aeroe. The plant is going to supply the villages St. Rise and Dunkaer with heat. Expected start of construction: August 2000, ready to deliver heat in 2000/2001. The production is budgeted to 3,400 MWh per year. 50% of the energy production comes from thermal solar heating and 50% from a wood pellet boiler. Heat storage in a steel tank forms part of the plant.

**District heating in Soeby**

A scheme for a "bare field project" based on a wood chip boiler combined with thermal solar heating has been prepared. The initiative originates from Renewable Energy Organisation of Aeroe. A connection campaign was run in 1999, the response was, although positive, not sufficient for a start up. A re-launch of the project will take place towards the end of year 2000. Production is budgeted to 6,400 MWh per year.

**Neighbour Heating Plants and Plans for Heating of the Rural Districts**

The Danish Energy Agency´s Data Office is working on a geographical analysis of potential "bare field" neighbour heating plants on Aeroe. Heating plans and new initiatives for neighbour heating projects are to be based on this analysis. Planning will take place in 2000/2001.

**Supply of Heat to Individually Heated Properties**

From 2001 “Aeroe Elforsyning” (Aeroe Electricity Utility) wants to offer delivery of heat to this type of property on similar terms as those available to district heating consumers. This will be a new type of service: the plant is financed and maintained by Aeroe Elforsyning and the heating bill is paid in monthly instalments. Solar collectors will be on offer in combination with a biomass boiler. The individual consumer will still have the possibility of owning his/her heating plant.

**Energy-savings**

At the moment work is concentrated on raising financial support for a project which presuppose a 20% reduction in electricity consumption after 3 years, and after 10 years a further 30% reduction. These savings will be obtained through a change in consumer-habits and the use of the best technology available. It is hoped that this project will be ready to roll in 2001. Electricity-savings through conversion of electrically heated properties to other sources of heating have started and will continue.

**Other Projects**

► An analysis of the flow and amount of waste products on the island is near its conclusion. The analysis also evaluates the possibility of waste used in the heat and power production.

► A continuous evaluation of the financial possibilities, through the use of PV in the supply of energy, will take place.

► A continuos evaluation of the use of hydrogen storage/fuel cells in the supply of energy and the transport sector will take place.

► A continuos evaluation of technical and financial possibilities through adaptation of electric cars and other forms of environmentally protective types of transport in the traffic pattern, will take place.

► Information about the complete project is an important part of the work

► Co-operation is an important element in the complete project. Steps have been taken to join forces with other Danish islands, and steps will be taken to co-operate with foreign projects of the same type during 2000. Renewable Energy Organisation of Aeroe is a member of ISLENET.

**Who Introduced Renewable Energy on Aeroe?**

"No to nuclear power" movement and oil crises in the 70'es were reasons for a green wave in Denmark. The wave found Aeroe in the beginning of the 80'es where a group of so-called ordinary people were the initiators of the local renewable energy projects: It was a smith, a farmer, a couple of teachers, a bank manager and so on. This group was later organised as members of the board in the Aeroe Energy Office, a society with more than 200 members from the island supporting the work.

The 80'es were the period of the pioneers: Solar collectors were build in the garages, local smiths tried to start a windmill production.

3 of the turbines on the island originate from this production.

The windmill park was opened in 1984, for a short time the biggest park in Denmark.

The pioneer-period culminated on Aeroe with the erection of Aeroeskoebing Energy Plant in 1989, a test and demonstration plant where some of the elements were straw boiler, solar absorbers, heat pump and fluegascondensors.

The Energy Plant sold the production to Aeroeskoebing District Heating Company. The legislation that made the renewable energy initiatives possible was the Energy Plan 81 from the Danish Energy Ministry, where Aeroe - among other rural areas in Denmark - was selected for the development with renewable energy as the natural gas pipe lines would not pass by.

As the consumers traditionally own the energy plants and distribution nets it was necessary to have a broad acceptance among the islanders before investing in new technologies. Public opposition was prevented through a high information level.

The first years of the 90'es were a quiet period after the bankruptcy of Aeroeskoebing Energy Plant due to falling oil-prices. It was not a period where new spectacular projects saw daylight.

In 1994 Marstal District Heating took over the role as initiators of new projects. They constructed a 75m$^2$ thermal solar heating test plant. The information gained was so interesting that it resulted in a decision to build a full-scale thermal solar heating plant in 1996. Aeroeskoebing District Heating followed the example in 1998.

Beside the more striking projects, the 90'es were signified by a growing acceptance of renewable energy among the islanders. This was made possible by the Danish Energy Agency who supported the information work: Aeroe Energy and Environment Office informed the consumers of individually heated houses and arranged education among the local installers of small scale equipment. More boilers and solar heating systems were installed. In 1997 the Renewable Energy Organisation on Aeroe (the RE-Organisation) was formed as a result of the Renewable Energy Island initiative of the Danish Government. The RE-Organisation consists of the mayors of Marstal Municipality and Aeroeskoebing Municipality, representatives for the boards of management for Aeroe Electricity Supply, Aeroe Farmers Association, Aeroe Energy and Environment Office as well as the operational managers from Marstal District Heating and Aeroeskoebing District Heating.

The RE-Organisation is a forum where new energy initiatives see daylight, and where the initiatives are co-ordinated.

**Barriers**

<u>The barriers in the 80'es were among others:</u>

► New and unproven technologies

► Lack of knowledge among consumers and authorities

► Approvals from the authorities were extremely delayed

<u>Some barriers in the beginning of the 90'es:</u>

► A decline in activities due to the bankruptcy of the "flagship" - the Aeroeskoebing Energy Plant

► Lack of local organisation on a political level

► Resistance towards erection of more and bigger wind turbines among the effected residents and a group of local politicians

<u>Some Barriers of the late 90'es:</u>

► Lack of organisation concerning the implementation of renewable energy in individual heated houses

► Lack of local biomass for district heating or CHP

► Producing biomass for energy is not economically attractive for the farmers

► Production of energy-crops in short rotation is prohibited in coastal areas

► Complicated and long-drawn-out administration for coastal areas concerning erection of wind turbines and (in one case) district heating on solar

► Although the islanders are positive towards renewable energy, there is still inertia when they are asked to act even though there are only benefits

► The local economy is vulnerable to mistakes

► Lack of possibility for financing energy savings for the poorest

**Organisation**

The Renewable Energy Organisation of Aeroe was established in 1997 as an activating forum to support the conversion of the energy production on Aeroe to renewable energy. The Renewable Energy Organisation of Aeroe is to:

► act as an inspirator and catalyst with regard to new RE initiatives

► act as a sparring partner and maintainer of RE-projects in progress

► co-ordinate renewable energy activities on the island

At the moment Renewable Energy Organisation of Aeroe is in the process of establishing itself as an independent institution under the same name. The objectives and members of the independent institution are identical to the present set-up. The new organisation will honour agreement entered into by the former organisation.

The following municipalities and organisations are represented in Renewable Energy Organisation of Aeroe:

► Marstal municipality, the mayor - chairman of Renewable Energy Organisation of Aeroe
► Aeroeskoebing municipality, the mayor - vice-chairman of Renewable Energy Organisation of Aeroe
► Marstal municipality, the chief executive
► Aeroeskoebing municipality, the chief executive
► Marstal District Heating Company, the manager
► Aeroeskoebing District Heating Company, the manager
► Aeroe Electricity Supply, the chairman
► Aeroe Farmers Association, a member of the board
► Aeroe Energy and Environment Office, the chairman

It is possible to include other partners in the organisation.

The Renewable Energy Organisation of Aeroe has employed a co-ordinator. The employment is supported financially by the Danish Energy Agency and The Green Job Pool.

<u>New projects:</u>

At the beginning of a new project a working party is set up consisting of representatives from the consumers, consultants, and representatives from the Renewable Energy Organisation of Aeroe. When the project approaches its implementation a board with consumer representatives is established to take charge of administration and implementation.

Established companies such as district heating companies and electricity distribution are responsible for their own projects.

**Contact Information**

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# Gotland (Sweden)

## General Information

**Population:** 58,000

**Area (km$^2$):** 3,140

Gotland is the largest island in the Baltic Sea and located south-east off the mainland of Sweden.

## Introduction

A few years ago Gotland was dependent on the Swedish mainland for its energy supply, which at that time was very unstable. A step away from dependence was taken when the largest town on the island introduced a district heating system. This system has used many different kinds of energy sources, of which most of them were renewable. Later there were district-heating systems in three other towns, which were all based upon renewable energy resources. Next to this was a group of wind power enthusiasts who got the idea of installing wind turbines on the base of selling shares in wind turbines as a financing method. By doing this they could raise the necessary investment capital and at the same time increase public awareness and interest in renewable energy. Today there are more than 130 turbines installed on the island.

## Energy Demand

Energy Demand by Sector in 1998:

| Sector | Demand in GWh | Percentage of Total Demand |
|---|---|---|
| Transport | 950 | 21.5% |
| Industry | 2,100 | 47.5% |
| Agriculture | 200 | 4.5% |
| Public Sector | 200 | 4.5% |
| Buildings | 975 | 22% |

Source: Gotlands Kommun, 2000

## Energy Supply

Energy Supply by Source in 1998:

| Source | Energy Supply in GWh | Percentage of Total Energy Supply |
|---|---|---|
| Coal | 1,695 | 38.3% |
| Petroleum | 1,365 | 30.8% |
| Imported Electricity[1] | 875 | 19.8% |
| LPG | 80 | 1.8% |
| Bio-energy | 256 | 5.8% |
| Wind power | 62 | 1.4% |
| Heat pumps | 56 | 1.3% |
| Waste heat | 25 | 0.6% |
| Biogass | 11 | 0.2% |
| Renewanbles Total[2] | | 19.2% |

Source: Gotland Energy Agency, 2000

## Wind Power

The development of wind power on Gotland began in the late 1980's. Through the establishment of wind energy co-operatives the widespread ownership of wind turbines has expanded. Today more that 2,000 households on Gotland own shares in wind turbines through local wind energy co-operatives.

The municipality has taken an active role in the promotion of wind power and has developed a plan for wind energy exploitation for the southern half of Gotland. The amount of electricity generated by wind power is expected to at least double within the next 5 years. Due to the shortage of sites on the island there are plans to build more wind farms in the sea. The largest currently being planned is an 80MW installation to be located off Gotland's south-east cost.

At the beginning of year 2000 there were over 130 wind turbines installed on the island.

Some of the Wind Parks on Gotland:

| Wind Park | Number of Wind Turbines | Capacity of Turbines | Total Capacity |
|---|---|---|---|
| Näsudden | 80 | 500kW | 40MW |
| Bockstigen Offshore Wind Farm | 5 | 500kW | 2.5MW |
| Smöjen | 10 | 2x500kW<br>4x 660kW<br>4 x1.5MW | 9.64MW |
| Storugns | 6 | 660kW | 3.96MW |

Source: Energy and Environment Projects on Gotland, 2000

Total energy production from wind power on Gotland is around 130 GWh. In 1999

1 50% of the 875 GWh electricity imported via undersea cable from the Swedish mainland is based on renewables.

2 This figure includes the renewable energy electricity imported from the Swedish mainland.

electricity by wind power corresponded to approximately 15% of the island's consumption.

**Biomass**

The use of district heating plants is already well developed on the island with district heating systems in the communities of Hemse, Slite, Klintehamn and Visby. These heating plants are fuelled up to 90% by renewable energy sources.

Bio-fuelled District Heating Plant in Visby:

The World Heritage City of Visby consists of many unique buildings and mediaeval ruins that are build from limestone. These structures are particular sensitive to air pollution – caused to a large extent by the emissions from oil-fired heating boilers. Due in part to a desire to protect these valuable buildings from further decay a district heating system has been in operating in Visby for the last 20 years. Around 95% of the energy supplied to the district heating network comes from renewable sources. This cleaner and $CO_2$ neutral energy comes in various forms, the largest contribution being from wood chips – a by-product of local saw mills. The use of oil for heating has been reduced by 75% and sulphur discharge from oil burning furnaces has been reduced by 95% since 1980.

Biogas from the town's landfill site and wastewater treatment plant is also used to produce heat for the network. In addition to this a 10MW heat pump is used to extract "free" heat from the sea. Altogether district-heating covers more than 75% of the city's heating needs – helping to keep the air free from pollution to the benefit of Visby's inhabitants and their culture heritage.

Biogas Demonstration Plant:

A biogas demonstration plant is under construction at Lövsta agricultural college to assess the possibilities for biogas use and production with farming. The manure will be used to produce methane gas that will provide heating for the college buildings – thereby reducing the need to use fuel oil.

**Solar Energy**

Solar energy is largely under-utilised today apart from a small number of projects using pool heating and domestic hot water systems.

Due to the fact that Gotland has the most sun hours in Sweden and a large summer population from tourism the potential from using PV and solar thermal installations in buildings is great.

The municipality and university are developing a demonstration project to use solar energy to power a seawater based cooling system for the new public library and university buildings in Visby. This system could have widespread applications in other buildings in Visby if proved viable.

**Alternative Vehicle Fuels**

Planning and the development of infrastructure that can reduce the need for vehicles are an important element in the municipality's strategy for reducing $CO_2$ emissions.

The municipality has been investigating the possibilities to replace fossil fuels in the transport sector on Gotland. Biogas, ethanol, electricity and rape-seed oil are some of the areas currently under evaluation.

To set a good example and as part of it's commitment to phase out fossil fuel use, the local authorities on Gotland have acquired around 60 vehicles that can be fuelled with rape seed oil. In the towns of Visby, Hemse and Slite there are now also commercial rape seed oil filling stations for public use. Other organisations on the island which have chosen to use rape seed oil driven vehicles as part of their environmental programmes include Skogsvårdstyrelsen and the Hessela collective. These organisations have their own pumps and stock their own rape seed oil.

Investigations are under way into the establishment of a bio-ethanol production factory at Roma where the existing plant that previously produced sugar from sugar beet is now being closed down. Should this prove viable then the municipality will increase its use of bio-ethanol in the transport sector. Exporting bio-ethanol will help to compensate some of the island's fossil fuel consumption that cannot be replaced by renewable energy sources.

Biogas has been considered for use in public transport and in agriculture.

**Recycled Energy**

Reducing energy consumption through energy efficiency measures is an essential element in developing a sustainable energy system. Re-using excess heat from industrial processes is one way that the overall energy demand on the island can be reduced.

One of Europe’s largest cement factories is located on Gotland in the town of Slite. The company Cementa is responsible for over 1/3 of the energy consumption on the island. Excess heat is already being used to supply the district heating system in Slite.

In 1999 Cementa were awarded a grant from the Swedish Ministry for the Environment for an installation for converting excess industrial heat into electricity. With the help of Vattenfall, the state owned electricity company, action has been taken to reduce the factory’s impact on the environment. An installation to generate electricity using steam created from waste heat will be commissioned in year 2000. Using the surplus production heat will provide an estimated 50GWh/year – 25% of the factory’s energy demand. In addition to this excess waste heat is also supplied to nearby greenhouses where it increases productivity and reduces the need to use fossil fuel.

**Policy**

Eco-programme for Gotland:

In October 1996 the Municipality Council of Gotland passed the Eco-programme for Gotland which identifies the municipalities goal that the island should become a Zero-Emission Zone and that Gotland is to become an ecologically sustainable society within the course of a generation.

Regarding energy the following are specified:

► Gotlandic dependence upon fossil carbon resources shall decrease to a level compatible with long term climate stability. Fossil fuels shall be replaced with renewable energy

► Gotlandic renewable energy shall be developed until it suffices for all the necessary functions of society

► Society shall be organised in such a way that the need for transport energy supply be minimised. The Gotlandic renewable energy shall suffice for all necessary transports of people and goods on the islands as well as to and from the island

► Buildings shall be designed in such a way that the need for energy supply for heat and light be minimised. The Gotlandic renewable energy shall suffice for all household needs

► Equipment shall be selected so as to minimise the need for energy supply for technical purposes. The Gotlandic renewable energy shall suffice for all necessary operations of tools, machinery and production processes.

The overall aim to develop an ecologically sustainable society has been reflected in many of the municipalities other plans and documents such as Vision Gotland 2010, the Agenda 21 plans, the regional development programme and Energy 2005 - the municipality’s energy plan.

Energy 2005:

Energy 2005 was approved by the municipality in October 1999. Energy plans are required by law for municipalities in Sweden. The combination of renewable energy with measures that increase the efficiency with natural resources are uses is a central part of Gotland’s strategy for realising a sustainable society.

Below are mentioned some of the elements in Energy 2005:

► 40% of the island’s total energy needs to be supplied by renewable energy sources and recycled energy sources by year 2005

► reduce the use of fossil fuels

► increase the use of renewable energy

► expand the district heating networks

► district heating shall be at least 90% bio-fuelled

► increase wind power installations up to 120MW by 2005

► reduce the amount of electricity

These plans have been approved by a majority of elected representatives and were developed in consultation with local actors and the population at large.

**Contact Information**

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# Samsoe (Denmark)

## General Information

**Population:** 4,300

**Area ($km^2$):** 114

## The Official Danish Renewable Energy Island (REI) – Introduction

In the Danish governments energy action plan Energy 21 from 1996 it was decided that a Danish island as a demonstration project should become a Renewable Energy Island (REI), e.g. an island self sufficient from renewable energy sources, including transportation, within 10 years. The overall objective is to reveal technical possibilities for converting an entire community to renewable energy only, and to cast light on the organisational and financial prerequisites for a conversion of this type.

The target groups for the demonstration project are local communities not only in Denmark and the European Union, but also globally. In November 1997 the island of Samsoe was selected among five candidates to be the official Danish REI.

## Objectives of the Official Danish REI

► that the island's heating and electricity needs be met solely by renewable energy sources in the course of a ten-year period

► make the transport sector more efficient, thus reducing fossil fuel energy consumption in this sector. The various possibilities for a partial transition to renewable energy sources in the transport sector will also be explored

► use the Samsoe project's demonstration and information activities to promote the use of renewable energy not only in the rest of Denmark, but also abroad. Samsoe, as Denmark's official Renewable Energy Island, will thus demonstrate not only Danish renewable energy technology, but also Danish energy planning and management.

► the energy island project has the explicit objective to create an appreciable number of new jobs. The ten-year period of transition to 100% renewable energy in the heating and electricity sectors will on average create 40 work-years of construction work, as well as 40 permanent new jobs in the renewable energy sector. The potential for new jobs in the service trades due to energy island tourists and guests in the important spring and fall seasons have not been examined.

## The Energy Plan for 1998-2008

Power Supply:

On Samsoe there has through the years been a power production from small wind turbines. In the year 2000 the establishment of 11 new 1 MW wind turbines will take place: 3 in the town of Tanderup, 3 in Permelille and 5 in Brundby Mark.

Then 75% of the power consumption is produced by wind turbines. The remaining 25% will be produced from biogass and combined heat and power plants. This will happen in 2004.

Heating:

In the future 60% of the homes will be heated from district heating plants. The remaining 40% of homes will install individual solar heating-, wood pills-, and heat pump systems.

District Heating:

Today 90% of the homes in the town of Tranebjerg are connected to a straw-based district heating plant.

The new district heating system will be established in the following villages and by the energy sources mentioned:

| Town | Energy Source |
|---|---|
| Nordby/Maarup | Woodchips and solar heating |
| Ballen/Brundby | Connected to the district heating plant in Tranebjerg |
| Kolby Kaas/Kolby | Heat surplus from the ferries |
| Besser area | Biogas |

Source: Samsoe Energy Company, 2000

Onsbjerg and the other villages are not yet decided.

Neighbouring District Heating:

Small villages can use district heating on a small scale, where local farmers – apart from their own demands – can supply the neighbours with heat from straw-, biogas- or other biomass plants.

The Transport Sector:

It is a difficult task to convert the transport sector to renewable energy. The first thing to be done is the installation of 10 offshore wind turbines to produce the same amount of energy for transportation as consumed at the moment.

In the long term the electricity from the wind turbines can be used for electricity cars and hydrogen vehicles.

Offshore Wind Turbines:

The 10 offshore wind turbines each with a capacity of 2.5 MW will be erected at Paludans Flak about four kilometres south of Samsoe.

Examination by divers will take place during the year 2000, and the installation of the turbines in the year 2002.

**Status for the Renewable Energy Island Project by August 2000**

► 3 wind turbines of 1 MW each and 8 wind of 1 MW each were commissioned in March and July/August 2000 respectively

► a great part of the municipal buildings have had installed electric saving equipment

► there has been installed heat saving equipment in approximately 15% of the dwellings owned by retired persons

► there has been installed approximately 50 solar water heaters

► there has been installed approximately 50 heat-pumps and wood-pellet boilers

► they are in a detailed planning process, which will result in two new district heating systems in 2001-2002 for four of the larger villages on the island - one system based on straw and the other system based on 2,500 $m^2$ solar heating and a combined biomass boiling system

► they are in in-depth discussions with consumers representatives from five smaller villages whether there shall be established district- or neighbour heating in their respective villages

► they are in phase-2 investigation concerning the off-shore wind farm – it is planned to install 10 x 2.5 MW in 2002

► the municipality have leased 4 electric cars

► a lot of delegations, TV and journalist has visited the island (from Japan, USA, England, Italy, Belgium, Germany, Sweden, Norway…)

**Wind Power**

Onshore:

In 1996, Samsoe had 8 wind turbines with a total capacity of 376 kW and annual wind penetration was 6%.

By August 2000 11 x 1MW Bonus wind turbines were commissioned and penetration has increased to a minimum of 75% of the total electricity consumption.[1] Two of the wind turbines are owned co-operatively, nine are privately owned.

Offshore:

Offshore wind energy will be installed by a 25 MW wind farm - 10 turbines x 2.5 MW - at the South of Samsoe. Thus, by an underwater sea-cable, making Samsoe a net exporter of electricity to the mainland of Denmark.

The first planning phase began in the autumn of 1998. Specialists from consultant firms, RISOE and ARKE conducted this preliminary study. Samsoe Energy Company co-ordinated the project. The study emphasised the importance of public support from the local population, their officials and regional authorities. Widespread public support may be the deciding factor that will make this ambitious undertaking possible. The Energy Company followed up and applied for further permits, and the Danish Energy Agency conducted another study in the fall of 1999, a hearing of all regional and national parties that could have potential interests in the outcome of such a decision. This round of talks reduced the three potential sites to one sole site, an area south of the island. The windmills will be erected in 2002 if all goes well.

**Barriers**

► economical investments related to the change to renewables is often a barrier – this is why consumers need financial support to some renewable energy systems. Approximately 40% of the 4,300 inhabitants on Samsoe are retired persons, and for o lot of them it is a barrier to make “long term” investments

[1] 75% penetration is guaranteed by the wind turbine manufacture Bonus, but probably 100% penetration will be provided.

► as an island with a unique nature it can be a problem to install some renewable energy technologies – they have experienced and are still experiencing planning problems because of the County and owners of summer cottages (people that live outside the island).

## Organisation

Samsoe Energy Company:

Samsoe Energy Company was established to implement Samsoe as an REI. This organisation was created from the philosophy that all activities related to the REI-project should be controlled by the local community – by authorities, business, farmers and NGO's. This company consists of representatives from Samsoe Municipality, the Commercial Council, the Farmers' Association and the Energy and Environmental Office. Samsoe Energy Company has set up a secretariat to co-ordinate the future projects and activities.

Samsoe Energy and Environmental Office:

The NGO most involved in the process is Samsoe Energy and Environmental Office (SEEO). An energy and environmental office is a local non-governmental association, which provides free, impartial information and guidance on energy conservation and utilisation of renewable energy sources. At the same time the energy offices initiate many energy and environment activities in their local areas. Today there are 21 energy and environment offices in Denmark. 18 of these are subsidised by the Danish Energy Agency for their educational work on energy and for helping people applying for subsidies on different renewable energy sources from the State. Most of the offices employ one or more energy advisers, who are responsible for the daily work.

## Contact Information

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# Corsica (France)

## General Information

**Population:** 249,737 (1990)

**Area ($km^2$):** 8,721

Corsica is a department of France and the island is situated in the Mediterranean Sea Southeast of France.

## Electricity Capacity

Installed Electricity Capacity in 1999 by Source:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants[1] | 357 MW | 73% |
| Hydro Power | 132 MW | 27% |

Source: Torre, et al, 1999

An electric cable connects Italy to the island of Sardinia via Corsica. The Corsican electric grid has the authorisation to take 50 MW from the cable.

## Electricity Production

Electricity Production in 1999 by Source:

| Source | Percentage of Total Production |
|---|---|
| Thermal Plants [2] | 70% |
| Hydro Power | 30% |

Source: Ferrari, 2000

During summer, thermal plants provide almost the total electricity production.

## Energy Plan

Due to the success with the utilisation of renewable energy sources on Corsica, the Corsican local authorities, the French Electricity Board (EDF), and the French Environment and Energy Agency (ADEME) have decided to launch a 3 year development plan in order to reach 50% of electricity consumption from renewable energy.

The aim of this plan is threefold: to promote an increase in production of renewables for the grid, reduce the costs to consumers by more emphasis on the use of local energy sources and efficient appliances, and to decrease CO2 emissions. If all goes according to the plan, the demand will decrease for the two oil central power stations (Bastia and Ajaccio).

According to this plan, by 2003, 52 MW of wind power (by the Eole 2005 programme) and 15 MW of hydro-electricity will be installed.

The technical potential of wind energy in Corsica has been identified to 433 MW. The economical potential is estimated at the level of 100 MW. In the frame of the Eole 2005 programme, 11 projects have been approved for a total of 52 MW.

Together these new installations should produce 200 GWh/year for the Corsican grid. The purchase tariff will be secured by EDF for wind electricity for a 10 year period (between 0.053 and 0.061 Euros), the hydro electricity will receive 0.3 Euro cents more than the normal price (0.02 FF). The group is also considering the potential for small-scale hydro generation, as the potential is under exploited - only 6% of hydro electricity is supplied by small installations.

In order to reduce peak consumption in winter, mainly due to electric heating and lightning, energy efficiency will be encouraged in the commercial and domestic sectors. An attempt will be made to educate people about energy use in order to reduce peak energy demand in winter. 494 MW of power is used during only one third of the year. Advertising will be organised, to promote solar water-heaters, wood heating, low consumption lightning and efficient domestic appliances.

Local authorities, the energy agency ADEME and EDF will invest 30.5 million EURO, and it is expected, according to ADEME's analysis, without counting the energy benefits, that this will result in supplementary economic activity of 183 million EURO in 5 years and the creation of more than 500 new jobs.

These plans will be in addition to subsidies, which already exist for solar thermal: 600 EURO for a household to install a solar water-heater and a subsidy of 60% for companies to install solar water heaters. Hospitals, campsites, hotels and restaurants are the main beneficiaries of this subsidy.

[1] Including 50 MW of import from Italy
[2] Including import from Italy

## Contact Information


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EuroRex (www.eurorex.com)

# Crete (Greece)

## General Information

**Population:** 540,054 (1991)

**Area (km$^2$):** 8,260

Crete is situated in the south-east of the Mediterranean Sea. Crete constitutes a region in Greece.

## Introduction

Crete is an ideal area for the development of renewable energy sources due to the availability of a rich and largely under-exploited renewable energy potential, the high investment interest and the positive attitude of the public towards renewable energy exploitation.

Crete faces a chronic energy problem caused by the high rates in energy and power demand and the reluctance of the population to accept the installation of new thermal power stations.

## Electricity Demand

Total demand in 1999 was 1,921 GWh.

Electricity Demand by Sector in 1999:

| Sector | Percentage of Total Demand |
|---|---|
| Domestic | 38.16% |
| Industrial | 9.22% |
| Tourist & Commercial Sector | 39.69% |
| Agriculture | 4.18% |
| Street Lightning | 1.45% |
| Public Sector | 7.30% |

Source: Regional Energy Agency of Crete

## Electricity Capacity

Installed Electricity Capacity by Source in 1999:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Thermal Plants | 514.4 MW | 89.9% |
| Wind | 57.8 MW | 10.1% |

Source: Regional Energy Agency of Crete

## Electricity Production

Electricity Production by Source in 1999:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 1,820 GWh | 94.5% |
| Wind | 96 GWh | 5% |
| Other Renewables | 9 GWh | 0.5% |
| Total Renewables | 105 | 5.5% |

Source: Regional Energy Agency of Crete

## Solar Thermal

More and more households and hotels install solar systems for water heating. It is estimated that 35,000 systems have been installed on Crete.

## Renewable Energy Potential

Potential for Development of Renewable Energy on the Crete:

| Renewable Energy Source | Potential |
|---|---|
| Waves | Medium |
| Tidal | Low |
| Biomass | Medium |
| Geothermal | Low |
| Hydro | Low |
| PV | High |
| Solar Thermal | High |
| Waste to Energy | Medium |
| Wind | High |

Source: CEEETA, 1997b

## Energy Policy

The Region of Crete has since 1994 adopted an energy policy, which gives a particular emphasis on the utilisation of renewable energy sources.

In the framework of this policy, it has set the goal to make Crete “a privileged field in Europe for large scale applications of renewable energy sources”.

The policy not only faces the shortage of electricity power in Crete, but also introduces intensive measures for renewable energy sources and rational use of energy, as well as the introduction of new energy technologies in the energy system.

**Implementation Plan for the Large Scale Development of Renewable Energy Sources in Crete**

Objective:

► 39.4% of the total annual electricity demand in 2005 by renewable energy sources

► 45.4% of the total annual electricity demand in 2010 by renewable energy sources

Timeframe:

Year 1998 to 2010.

Focus:

► suggest actions concerning each renewable energy technology

► estimates their impact in the energy system

► verify their economic feasibility

The main focus for the implementation plan is the exploitation of renewable energy sources for electricity production since the major problem in Crete's energy system is the inability of the existing electrical system to meet the increasing demand.

Electricity Production:

| Year | 2000 | 2005 | 2010 |
|---|---|---|---|
| Thermal Plants | 469 MW | 546 MW | 584 MW |
| Wind Farms | 89.3 MW | 200 MW | 250 MW |
| Biomass Units | 20 MW | 40 MW | 60 MW |
| Small Hydro | 0.6 MW | 6 MW | 6 MW |
| PV Installations | 0.2 MW | 2 MW | 4 MW |
| Pumped-storage | 0 MW | 125 MW | 125 MW |
| Total Renewable Energy Penetration | 19% | 39% | 45% |

Source: Zervos, 1999

Solar Hot Water Systems:

Intensive use of solar water systems at the domestic and tourist sectors:

► 85,000 m$^2$ installed total in 2000

► 365,000 m$^2$ installed total in 2005

► 500,000 m$^2$ installed total in 2010

Energy-Saving Measures:

► Replacement of incandescent bulbs at the residential sector residential sector and in street-lightning

► Passive and hybrid systems for cooling at dwellings, hotels and bungalows

**Contact Information**


| | |
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Information provided by Regional Energy Agency of Crete

Zervos et al, 1999

# Cyprus

### General Information

**Population:** 651, 800 (1997)

**Area (km$^2$):** 9,251

The island of Cyprus is situated in the eastern Mediterranean.

### Primary Energy Sources

Primary Energy Sources in 1997:

| Source | Percentage of Primary Energy |
|---|---|
| Oil Products | 90% |
| Coal | 6% |
| Solar | 4% |

Source: Kassinis, 1999

Cyprus does not have any indigenous fossil-fuel resources. It is almost totally dependent on imported energy products, mainly crude oil and refined products. Solar energy is the only indigenous source of energy in Cyprus. The contribution of solar energy to the energy balance of the country is about 4%.

The burden of the costs of energy imports on the economy of Cyprus is considerable. Imports of energy in 1997 amounted to 134.3 million C£, which corresponds to 61% of the country's total domestic exports and 9.1% of the country's total imports for home consumption.

### Solar Water Heaters

Solar energy is utilised extensively by households and hotels for the production of hot water. Indeed, Cyprus is a leading country in installed solar collectors per capita - 0.86 m² of solar collector per capita. Solar energy is also used in non-thermal applications.

Progress:

Solar water heaters were first fabricated and installed in 1960. Since then a remarkable expansion in the utilisation of solar water heaters has taken place rendering the country among the leaders on the basis of total number of solar water heaters in use per person.

Progress was slow, during the first years, on account of the defects in design, which led to low efficiency, high cost and operational difficulties (e.g. leakage). With engineering developments and rationalisation of production, the defects were eliminated to a large extent and the cost kept at constant level, witnessing an impressive increase in production.

Today, there are about ten major and twenty manufacturers of solar water heaters in Cyprus, employing about 300 people and producing about 35.000 m² of solar collectors annually.

The estimated penetration of solar water heating systems in the different categories of buildings as on 1.1.1999 was for houses 92% and for hotels 50%.

The estimated current area of solar collector in working order in Cyprus is 600.000 m$^2$, and the annual solar thermal energy production is 336,000 MWh/year.

As a result of the extensive use of solar heaters 4% of total $CO_2$ emissions are avoided (285.600 tones $CO_2$/year).

Technology:

The majority of solar domestic hot water heaters, put up on individual houses are of the thermosyphon type. Two solar collectors, with a total glazed area of 3 square meters, are connected in series to a hot water tank, placed at a height, just above the top of collectors. Since the city water supply is not continuous, a cold water storage tank is located above the hot water storage tank. The hot water tank is also fitted with an auxiliary electric 3 kW heater, which can be operated manually or automatically. The solar collectors are invariably of the flat plate type glazing.

Economics of solar heating in Cyprus:

The average daily solar radiation falling on a collector installed at an angle of 35° to the horizontal in Cyprus is 5.4 kWh per square meter. From test carried out at the Applied Energy Center of Cyprus the annual savings per square meter of installed collector area in Cyprus are 550 kWh.

The extra total cost required to install a solar water heating system on a house is around US$ 600. The payback period depends on the price of fuel displaced; in the domestic sector it is electricity where as in the other sectors it is fuel oil. In accordance with 1998 prices the payback period of a typical solar system, displacing electricity is estimated to be about four years.

Reasons for widespread use of solar energy in Cyprus:

A number of factors have contributed to the wide scale use of solar energy in Cyprus. The most important factor, contributing to this phenomenon is the enterprising industry. The industry identified correctly the prime application of solar water heaters and boosted the improvement of technology and promotion of product with vigour. Hot water is a primary need and solar water heaters can meet the need economically with an investment, which most Cypriot house owners can make, with out any significant inconvenience.

The sunny climate has tended to make solar heating more competitive. In hotels the maximum demand in summer matches very well with the flux of solar radiation which makes water heating systems more efficient and economic.

The government through the Applied Energy Center of the Ministry of Commerce, Industry and Tourism has helped the promotion of solar energy by:

► Providing technical support, consisting of testing of collectors, advice to industry for improvement of products and to consumers for efficient utilisation. The provision of technical support to industry proved to be very critical at the initial stages, but even now, the provision of technical support is necessary because most local solar water heater firms on account of their size cannot support research activities.

► Making the material used for fabrication of solar water heaters duty free.

► Providing technical support for the preparation of relevant standards.

► Making the installation of solar water heaters compulsory on state-built housing.

The government has given no subsidies and the growth of solar energy industry is in conformity with natural laws of economics and, hence, reasonably stable.

The main lesson to be learnt from Cyprus is that nothing succeeds like the exploitation of a properly identified application of solar energy, in this case solar water heating, by an enterprising industry, backed up by a co-operating government.

**PV**

Photovoltaic cells are in systematic use by the Cyprus Telecommunication Authority and the Cyprus Broadcasting Corporation to power telecommunication receivers and transmitters in remote areas.

**Energy Policy**

The main objectives of the Cyprus energy policy are the following:

- Securing energy supply
- Meeting energy demand
- Mitigation of energy consumption impacts on the environment
- Harmonisation of the island energy sector with the Acquis-Communautaire
- Energy conservation and development of renewable energy

Securing Energy Supply:

► Increase capacity of local refinery from 0.8 millions MT/year to 1.3

► Study the possibilities of applying diversification of primary energy sources for electricity production (coal and LNG).

Meeting Demand:

► Increase the installed capacity from 660 MW to 900 MW by the year 2000.

► Increase of storage capacity of petroleum products (possible locations to accommodate a new depot were identified).

Grant Schemes and Programme:

► Grant schemes – incentives for the promotion of biogas. The Government subsides up to 66% of the total investment.

► EAC purchases electricity generated by alternatives energy sources at the same price it sells to the domestic consumers.

► A grant scheme for the utilisation in the hotel industry was recently prepared.

► A grant scheme for energy conservation (installations of systems and equipment) was recently prepared.

Applied Energy Centre:

► Advise Government on energy matters regarding rational use of energy and development of renewables.

► Carry out energy studies.

**Future Plans and Programmes**

► Grant scheme – incentives for the promotion of solar energy in the hotel industry (thermal and photovoltaic applications) – subsidisation up to 50% of the total investment.

► Grant scheme – incentives for the improvement of the aesthetic view of existing solar systems in the domestic sector.

► Introduction of standards: durability tests for solar systems and components.

► Introduction of standards relating to PV cells; efficiency, durability, etc.

► Utilisation of solar energy for electricity production.

► Utilisation for solar energy for cooling and heating buildings.

► Future co-operation with all countries and organisations interested in solar energy.

It is important to note that the Electricity Authority of Cyprus is now committed to purchasing electricity produced from renewable energy sources at relatively high prices in order to boost the development of these sources.

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Information provided by Applied Energy Center

# Minorca (Balearic Islands, Spain)

## General Information

**Population:** 65,000

**Area (km$^2$):** 720

Minorca Island is part of the Balearic Islands (Mallorca, Minorca, Ibiza, and Formentera) and situated in the eastern part of the Mediterranean Sea.

## Renewable Energy Plan

Introduction:

In 1993 UNESCO declared Minorca as a Biosphere reserve. With this declaration Minorca was converted into an international reference for sustainable development.

This led to the formation of a Sustainable Development Plan, which also included a renewable energy plan.

One of the most important aspects of the plan is given by the present energy situation – a very low renewable energy penetration. Less than 1% of primary energy is from renewables.

The perspective for the plan is the maximum penetration of renewable energy and the main focus is on solar and wind energy.

Objectives:

► identification of the energy economy potential and the sources of renewable resources to mobilise

► identification of the economic and technical potential

► forecast of the degree of mobilisation and the interest of the actors concerned

► identification of political priorities for renewables in the context of island sustainable development

Wind Power:

It is possible when grid stability is taken into account to install 9 MW of wind turbines. The plan includes wind measurement, and viability and environmental impact studies of sites for wind turbines.

Solar Thermal:

Thermal solar energy has a large potential of approximately 12 MWh per year, on the basis of an installed panel surface of 15,100 m$^2$.

The medium term objective is about 8,000 m$^2$ of solar panels.

Actions include:

► special training for thermal solar system installers

► information and training for designers, architects and the building sector

► making demonstration projects, which exemplify solar concepts in new public buildings

► campaigns towards the hotel sector aiming to use solar energy

Solar Photovoltaic:

There is at present a research programme involving a 42 kW PV panel, but the current high cost limits the possibilities of grid connection. This is not the case if the PV is on a small scale, where the quality of services predominate the cost – this could be in protected areas, traditional applications for the rural areas and for communication.

Passive Solar:

► training and information on the traditional solutions and on new solutions aimed towards designers

► preparation of a catalogue of accessible solutions

Energy Savings and Energy Efficiency:

Energy savings and energy efficiency are additional objectives.

The municipal's public lightning system has been chosen as object of analysis and proposal regarding energy saving, taking into account that public lightning represents 6% of total electricity demand.

Major Sector and Actors:

Town Councils and Consell Insular:

The public sector is where the first steps are taken; integrate thermal solar applications into the principal public buildings, PV installations at monuments and tourist centres in natural areas, and passive solar design for new public constructions.

Tourism Sector:

To launch a campaign aiming to install 8,000 $m^2$ of solar panels in the island's tourist buildings.

Organisation:

The Consell Insular de Minorca is the principal actor for promotion and implementation of the Plan. The management of the plan should be the responsibility of an organisation created by the Consell Insular de Minorca. This body should promote renewable energy with the support from the international organisations involved, the International Scientific Council for Island Development (INSULA) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

The objectives of this management organisation are to:

► create co-operation between public and private actors

► identify the possibilities and potentials in different sectors

► assist with technical assistance

► identify additional financial resources

► co-ordinate promotion and campaigns regarding the possibilities and prospects of renewable energy

**Renewable Energy Potential**

Potential for Development of Renewable Energy for the Balearic Islands:

| Renewable Energy Source | Potential |
|---|---|
| Waves | Low |
| Tidal | Low |
| Biomass | Low |
| Geothermal | Low |
| Hydro | Low |
| PV | Low |
| Solar Thermal | High |
| Waste to Energy | Medium |
| Wind | Low |

Source: CEEETA, 1997b

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# Mauritius

## General Information

**Population:** 1,196,172 (2000 estimate)

**Area (km$^2$):** 2,040

Mauritius is situated in the South West of the Indian Ocean, east of Madagascar.

The country includes the island of Mauritius, with an area of 1,865 km$^2$; the island of Rodrigues with an area of 104 km$^2$ to the east; the Agalega Islands to the north; and the Cargados Carajos Shoals to the north-east, which have a combined area of 71 km$^2$.

## Introduction

In Mauritius, imported petroleum products account for about 90% of the total primary energy input. This figure has remained virtually constant for the past decade. The sugar industry, which consumes more than half of the island's energy requirement, is self-sufficient energy-wise, using bagasse, a by-product of sugar-processing, for all its energy requirements. Hydropower and solar water heaters are also utilised on a big scale.

## Electricity Sector

The Central Electricity Board (CEB) is a Government para-statal organisation under the aegis of the Ministry of Public Utilities, and is responsible for the generation, transmission and distribution of electrical energy in Mauritius and its dependency Rodrigues Island.

The country is electrified to 100%, and the domestic sector represents 90% of the total number of consumers accounting for about 38% of the total CEB's revenue. The remaining sectors are Commercial (8% of total) accounting for 32% revenue, and Industrial (2% of total) contributing the balance of 30% to revenue.

The economic development in Mauritius over the past decade has led to sustained rapid growth in electricity demand. Over this period, CEB has undertaken substantial investment to cope with an average increase of about 10 per cent per year in both power and energy demand. It is anticipated that in the decade ahead, the corresponding figures, though decoupled with G.D.P will continue to increase at an average rate of about 7 per cent, hence the further requirement of substantial financial resources. To cope with such a situation, generation from private companies is presently strongly encouraged, the more so that it should allow an enhanced production of electrical energy from bagasse a residue of sugar cane milling and a reliable source of renewable energy. Privatisation of the Power Sector is already advocated in certain quarters, but its impact on subsequent tariff levels with possible adverse incidence from the macro economic standpoint, is an object of concern in other quarters.

The history of electrical power generation in Mauritius dates back to the early years of the century, when hydropower started to be harnessed. During the first half of the century, some three hydro power stations of capacities ranging from a few hundred kilowatts to seven megawatts were progressively commissioned, as electrification progressed in the main urban areas of the country.

In the early fifties, diesel generating sets were first introduced for electricity generation at St. Louis, close to the capital Port Louis and by 1958, that Power Station had a total installed capacity of about 14 megawatts with eight medium speed generating units. Thereafter, in 1962, a new thermal power station was commissioned at Fort Victoria, within some 1.6 kms from St. Louis and comprising two 6.2 MW slow speed diesel generating units.

At about the same time, three further hydro power stations were commissioned island wide with capacities ranging from one to four MW. The two last hydro power stations were commissioned in 1971 at Ferney (2 x 5 MW) and in 1984 at Champagne (2 x 15 MW). It is today considered that with a total installed hydro capacity of some 60 MW, all the economically feasible hydropower projects have been completed. The corresponding average energy yield from hydropower is of the order of 100 GWh annually corresponding to seven per cent of total generation in 1998.

In the thermal power stations, further development took place at Fort Victoria from 1973 to 1978 with the installation of eight medium speed units of some 5.5 MW each, and the Power Station was further extended in 1989, again with the installation of two 9.8 MW medium speed units. At St. Louis Power Station, six 12 MW units were progressively installed from 1978 to 1981.

A first peak load power station with a 25 MW gas turbine unit was commissioned in late 1987 at Nicolay and subsequently, two further units of 25 MW and 35 MW respectively were added in late 1991 and early 1995. Those units operate also as emergency units and provide reliable back up to hydro peaking capacity during dry years, whilst ensuring to-day a loss of load expectation (LOLE) of the order of 26 hours annually.

The last base load Power Station was commissioned in 1992 at Fort George near Port Louis where 2 x 24 MW and 2 x 29 MW slow speed diesel units are now in operation and 1 x 29 MW unit on order. This Power Station will cater for 50% of total electrical energy requirement of the country in year 2000.

A feasibility study for new base load power requirement over period 2005-2020 is presently being carried out to determine the best development scenario, whilst taking also into consideration new environmental regulations enforced in Mauritius's legislation since 1991. The competitors for this future development appear to be conventional coal technology, combined cycle gas turbine technology and slow speed diesel units similar to those already installed at Fort George.

**Electricity Capacity**

Installed Electricity Capacity by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal | 288.5 MW | 60.1% |
| Hydro | 59.4 MW | 12.4% |
| Bagass | 132.4 MW | 27.5% |
| Renewables Total | 191.8 MW | 39.9% |

Source: http://ncb.intnet.mu/putil/ceb/sector.htm

**Electricity Production**

Electricity Production by Source in 1996:

| Source | Percentage of Total Production |
|---|---|
| Thermal Plants | 80.63% |
| Hydro | 9.02% |
| Bagass | 10.35% |
| Renewables Total | 19.37% |

Source: Saddul, 1999

**Renewable Energy from Bagasse**

Private energy generation from Sugar Factories with export of surplus energy from bagasse to CEB grid started as early back as 1957 when energy supply contracts were signed between CEB and two Sugar Estates. On account of the intermittent nature of supply, and the fact that such energy derived from bagasse was available during the crop season only (July to December), CEB had to continue in its investment programme independently, irrespective of installed capacity on sugar estates, and remuneration of energy from those private suppliers was consequently not very attractive. However, the contracts were periodically reviewed and in 1982, the first contract for the supply of electrical energy on firm power basis all year round was signed with the biggest sugar factory of the island (Flacq United Estates Limited – F.U.E.L.). That Sugar Company installed a 22 MW condensing turbine associated with a dual fuel boiler designed to burn coal as a replacement of bagasse in the inter crop season. The Power Station was commissioned in 1985, and since then produced and average of some 90 GWh to the CEB grid annually, with about 50% energy export derived from bagasse. A new 18 MW turbo alternator associated with consending turbine and coal/bagasse fired boiler was commissioned in late 1998 to bring total energy export to grid to some 170 GWh.

The next significant step forward was initiated in 1991 through the Bagasse Energy Development Programme (B.E.D.P.). After protracted debates involving the Government, the CEB and the Sugar Industry not less than nine different Power Purchase Agreements were signed in the period 1996 to 1997 between the Sugar Industry promoters and the CEB for period of 15 to 20 years. The PPA's were pertinent to three bagasse cum coal Firm Power Projects to operate some 8,000 hours per year, and five "continuous power" projects designed to operate on bagasse during the crop season only, i.e. about 2,500 hours/year.

In relative terms, nearly 20% of total national electrical energy will be derived from bagasse in year 2000, with a natural decline thereafter associated with a saturation of the bagasse potential of the country. In absolute terms the bagasse energy will have increased fourfold in the period 1994 to year 2000 with prospects of going significantly beyond the expectations of the B.E.D.P. in the medium term.

Today, electrical energy generation in Mauritius is dependent on imported diesel fuel and kerosene for about 75% of total generation, and on account of the present economic activity, the need is felt for desirable diversity in the primary energy sources, hence the declared policy of the Government of Mauritius to encourage coal/bagasse power generation to fully optimise the use of available bagasse as a renewable source of energy. A first 2 x 35 MW power station is expected to come into operation in early year 2000 at Belle Vue in the centre north of the island.

The other factors which have favoured the emergence of the Sugar Industry based Independent Power Producers and the development of bagasse based energy are as follows:

► The economic and strategic interest of the country to optimise it's indigenous renewable energy potential in a situation whereby some 90% of primary energy needs are imported.

► The clear policy of the successive Governments to give their full support to the Sugar Industry, on account of its position as the best net foreign currency earner in a context of more severe international competition coupled with a need to make necessary investment to upgrade obsolete equipment and machinery for an enhancement of efficiency;

► The rapid growth in power and energy demand corresponding to a yearly average increase of nine and ten percent respectively registered over a period of 12 consecutive years, starting from 1986;

► The need to replace ageing generating plants in the CEB diesel based power stations of Fort Victoria and St. Louis which have reached the end of their normal service life.

► The financial incidence of the considerable investment made by the public sector in a context where electrical energy tariffs were declining in real terms, thus adversely affecting profitability and financial equilibrium dangerously.

► The emergence of a new attitude in respect of environment impacts of new generating plant and more particularly emission of gases associated with the "greenhouse effect" leading to Government commitment in international forum to force mitigating measures upon the concerned sectors.

► The development of new technology with enhanced possibilities of energy conversion and energy use.

► The favorable impacts on grid interfacing with regard to diversified geographic location of generating plant island wide and spinning reserve response associated with conventional boiler technology.

**Renewable Energy from Hydropower**

Electricity generation in Mauritius started with the harnessing of hydropower as early back as 1904 and this has been the main source of electrical energy to the population until the early fifties, when diesel generators were introduced.

The size and topography of the island allows for only modest storage capacity, with the result that in spite of an average rainfall of 2 m over the territory, the average annual energy derived from the hydro sector is only of 100 GWh.

Rainfall is seasonal with 70% of precipitation usually being experienced from December to April. The growth of the population and the economic development of the country dictate that irrigation for agriculture together with domestic and industrial needs are priority candidates for water use. Thus hydro electricity generation is today being essentially considered as peaking and emergency capacity, except during relatively short high rainy periods.

The present installed capacity of about 60 MW comprises hydro turbines in the range of 1 to 15 MW unit rating installed over the period 1945 to 1984 at nine different locations. The latest power station commissioned in 1984 is of particular strategic interest for the quality of supply to the network on account of its feature to generate some 30 MW within only 120 seconds from order to start.

It is considered today that virtually all of the available water resources for hydro power have been harnessed.

**Other Renewable Energy Sources**

Solar Water Heaters:

Some 20,000 solar water heaters have been installed. This represents an 8% penetration of the household market.

Solar water heaters are used in many coastal hotels for hot showers. This is, however, on the decline as the technology has failed. Hotels are now having to recourse to gas boilers.

PV:

From a purely experimental point of view, a PV powered irrigation system is being tested in one of the river mouths where intensive cultivation is practised. A contract has been awarded in 1998 for a pilot project on the development, supply and installation of a PV system for street lightning and lightning of Government Building to promote the development of renewable energy sources on mainland Mauritius and Rodrigous Island. The pilot project will consist of the supply and installation of a total of 125 solar powered streets lightning units (to be installed in Mauritius, Rodrigues and Agalega Islands) together with the installation of a grid PV system on the New Government Centre building in the capital city of Port Louis.

Rodrigues Island is the best site where small-scale PV systems could replace the use of diesel generators. The University of Mauritius proposes to study the use of PV on Rodrigues island, paying careful attention to the water-pumping applications, problems with salt-intrusion to wells etc., and the general hydrology of Rodrigues, as well as the more straight forward technical aspects of PV water-pumping systems – e.g. size of array, type of pumps, economics of delivered water, and integration with existing diesel generating systems.

In Agalega Islands (population 300), PV electricity is provided to some 40 households. The project is funded by UNDP-GEF/SGP (Global Environment Facility/Small Grant Projects). A PV based Survival Centre for food storage and desalinisation is being set up.

Wind Power:

As part of the Government of Mauritius plan to diversify it’s of alternative energy sources, the Mauritius Meteorological Office (MMO) initiated a programme in the early 1980’s to evaluate the wind energy potential of Mauritius.

The survey for Mauritius has shown a major potential for exploiting wind energy at various sites. However, the wind energy programme needs to consider its exploitation in relation to the energy resources and capital investment costs. The case for exploiting wind energy is much clearer for Rodrigues Island, where electricity generation by other means is less universally available.

It is the policy of the government to promote the use of wind. Taking into consideration technological advancements in the field of wind energy, and the favourable wind regime as assessed by a study financed by UNDP in 1985, it has been agreed to encourage the development of wind farms in Mauritius and Rodrigues on a Build, Operate and Own (BBO) scheme by providing a proper pricing policy.

So far, all projects related to wind energy into electrical energy with a view to feeding the present grid have lamentably failed in both Mauritius and Rodrigues. Efforts form different agencies and organisations (UN, German Development Bank, Australian Trade Commission) in the setting up of small wind farms on the island have been commendable, but all have been damaged by cyclonic winds, corroded and finally dismantled. Lack of available funds, lack of appropriate technology and training and of regional co-operation are some of the discouraging factors.

The Government has sent out a request for expression of interest for the development of 5 MW wind farm on the main island of Mauritius.

Wave Energy:

In Mauritius, the Mauritius Wave Energy Project was conceived in 1958 focusing on the possibility of converting wave energy into electricity at Riambel, in the south of Mauritius. However, progress has been minimal.

Several problems associated with the wave project have been identified:

► proper siting of the turbines

► permeability and strength of the reef

► ecological impacts of the wave-ramp on the reef and coastal areas (salt water infusion)

► the effect of seasonal variation on the electricity output.

**Renewable Energy Project Priorities**

► maximise the use of bagasse

► setting up wind farms in Mauritius and at Canne Paul in Rodrigues

► use solar heaters and PV for hotels and government buildings

► use low energy street lights

**Contact Information**


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# Reunion (France)

## General Information

**Population:** 653,000 (1995 estimate)

**Area (km$^2$):** 2,512

Reunion is located in the Indian Ocean south-east of Madagascar. The island is an overseas department and administrative region of France.

## Electricity Capacity:

Installed Electricity Capacity by Source in 1998:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 192.5MW | 44% |
| Hydro | 126.6MW | 29% |
| Bagasse/Coal | 118MW | 27% |

Source: IEDOM, 1999

## Electricity Production

Electricity Production by Source in 1998:

| Source | Percentage of Total Production |
|---|---|
| Thermal Plants | 43.9% |
| Bagasse | 16.5% |
| Hydro | 39.6% |
| Renewables Total | 56.1% |

Source: ADEME Reunion, 1999

## Renewable Energy from Bagasse

There are two co-generation plants, Louis-Rouge and Le Gol, on the islands. They run on bagasse during the sugar season, and as conventional coal plants during the rest of the year. Producing 2 millions tons of sugar cane a year, the island has access to 640,000 tons of bargasse, the equivalent of 120,000 tons of heavy fuel.

The cost per kWh produced is perfectly competitive for an Overseas Department.

Bouis-Rouge plant was commissioned in August 1992 and has achieved excellent results hence it was decided to build a second plant near La Gol sugar mill. This plant was commissioned in the last quarter of 1995.

<u>The Bois-Rouge Concept:</u>

In order maximise the use of bargasse, a new type of power station was designed and built in Bois-Rouge. It was based on the application of the following principles:

► the power station build next to the sugar mill in order to minimise the transportation of bargasse

► the power station supplies process steam to the sugar mill and exports electricity to the grid

► the plant boilers generate efficiently (90% thermal efficiency) high characteristic steam (80 bars, 520$^o$C)

► in order not to storage large quantities of bargasse, the power station burns all of the bargasse as it is produced by the sugar mill

► when bagasse is not available (mainly during the inter crop season which last six months) a second fuel is used, and the power station is operated as a conventional plant producing electricity for the grid

► the impact of the power station onto the environment would have to be minimal (in particular as far as emissions are concerned)

The Bouis-Rouge Power Station is made on the following equipment:

► two boilers producing each 130 tons of steam can burn either bagasse or coal exclusively as well as any combination of the two fuels. Switching from one fuel to the other can be done on line automatically. The boilers are of the two drum multipass spreader-stoker type, with a two-stage super heater. Bagasse firing equipment is made on bagasse feeders that allow bagasse extraction and feed regulation from feed chutes. Coal feeders include slat conveyors and projecting drums located at the bottom of the coal chutes

► fuel gas cleaning equipment made of two distinct dedusting systems: one mechanical deduster designed to collect large particles which will be re-injected into the furnace, the second stage consisting of an electrostatic precipitator

► bagasse handling system which includes an indoor storage capacity of 1,000 tons needed to accommodate the different operating rates of the sugar mill and the power station, a set of conveyor belts and slat conveyors whose function is to carry an even quantity of bagasse to the boiler house

► coal handling facility including truck weighting, unloading, screening, grinding, two storage silos and a set of conveyor belts

► two turbo-generator sets of a capacity of 30 MWe each, consisting of two steam turbine each comprising a high pressure body and a low pressure body and a steam extraction system, two generators and two condensers

► two cooling system towers aimed at cooling down the condensers, the lube oil plant and the generators

► ash handling system

► two water demineralisation units

Bois Rouge and Le Gol Results:

The main challenges faced by the engineers and the operators were:

► the size of the plants (circa 60 MWe each) compared with the overall size of the island grid (260 MW)

► the necessity to switch automatically from on fuel to the other

► the necessity to meet at the same time the demand from the gird and the demand from the sugar mill which could vary in totally different directions

**Renewable Energy from Hydropower**

Hydropower is produced at Riviere de l'Est, Takamaka I & II, Bras de la Plaine and Langevin power stations.

Though the hydro potential is practically tapped, there are still a number of potential sites, where micro power stations can be installed.

**Solar Water Heaters**

Approximately 10,000 units are in operation. Through the "Abonnez vous au Soil" campaign, some 1,500 solar heater are installed every year.

EDF and ADEME have set up a structure to encourage households to purchase a solar heater by providing various "save energy" incentives. One of them is the provision of a soft loan of 5.5% interest rate. The campaign aims at sensitising the public on their contribution towards solving environmental problems such as climate change, acid rain etc.

**Other Renewable Energy Sources**

Geothermal:

20MW could be installed when the demand currently met by bagasse-coal plants need the installation of supplementary production means (2006). Two deep exploration boreholes were drilled in 1985 at the Grand Brûlé and Salazie sites. Although non-productive, these boreholes and associated studies have shown that potential exists for discovering exploitable high-temperature resources, especially at Salazie. It should be noted that in Hawaii, six boreholes were put down before a resource of 385°C was found at 2,100 depth.

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# Hawaii (USA)

## General Information

**Population:** 1,193,001 (1998)

**Area (km$^2$):** 16,729

State of Hawaii is the only island state and the southernmost state in the United States. Hawaii consists of eight Hawaiian Islands and a few other geographically unrelated islets located near the centre of the northern Pacific Ocean.

Below are specified population and size for the major six islands in Hawaii State:

| Island | Population[1] | Area (km$^2$) |
|---|---|---|
| Hawaii | 120,317 | 10,433 |
| Kauai | 50,947 | 1,430 |
| Lanai | 2,426 | 364 |
| Maui | 100,374 | 1,883 |
| Molokai | 6,717 | 673 |
| Oahu | 836,207 | 1,554 |

## Introduction

Hawaii, as is typical for many island areas in the Pacific Region, finds itself in a paradoxical energy situation. In spite of a wealth of renewable energy resources and a two-decade old supportive state policy, the state continues to rely on imported petroleum and coal for almost ninety percent of its energy needs. Faced with dwindling financial resources, Hawaii has had to opportunistically leverage its assets to generate investments in developing renewable energy resources, including research, development and demonstration projects to introduce new technologies, and commercialisation of promising technologies.

The primary components of the state energy strategy are to promote the use of energy efficiency and renewable energy in place of imported fossil fuels.

The Energy, Resources and Technology Division of the Hawaii Department of Business, Economic Development and Tourism, is responsible to ensure the reliability, security, and economy of energy supply, all in an environmentally responsible manner.

## Hawaii's Energy Profile

Twenty-five years have passed since the original oil crisis, and the need for Hawaii to diversify is energy resources and develop renewable energy has never been as great. In 1974 the state derived ninety percent of its total energy needs from oil. Imported petroleum supplied gasoline, diesel, jet fuel and electricity demand.

For decades the energy supply in Hawaii has been much less diversified than that of the United States as a whole. In 1997, 88% of Hawaii's total energy came from oil, 4.5% from biomass and municipal waste, 5.7% from coal, and 1.8% from other sources. By comparison in 1997, the nation relied on petroleum for only 37% of its energy, while natural gas supplied 22%, coal provided 22%, and nuclear power generated 7%. Hydroelectricity and other sources provided 12% of the nation's energy.

Hawaii's residents paid almost $2.2 billion (US) for energy in 1995, or 6.6% of the Gross State Product. On a per capita basis, energy bills are fairly low - forty-second in the US for 1995 - largely because of limited driving distances and the absence of heating and air conditioning in homes, but proportionately more is paid for the energy used. Overall, state energy prices were the fifth highest in the country in 1995.

By far the most oil-dependent of the 50 states, Hawaii imported 29% of its crude petroleum from Alaska in 1997 and the remainder from the Asia-Pacific region, primarily Indonesia. Oil exports from both areas are projected to decrease significantly by the year 2000, and thus reliance on other sources will increase. In recent years, use of oil for electrical power generation has dropped. About one-third of the total energy consumed state-wide is used for electricity. Through 1991 oil-fired generation fuelled about 90% of electrical power generation, but by 1997 the share had fallen to 75 percent, despite strong growth in demand.

On Oahu, two oil refineries produce the bulk of refined products used in the state. The refinery is driven largely by the disproportionate demand for jet fuel, given the state's reliance on air transportation as its economic lifeline to the rest of the world.

The state's Public Utilities Commission requires all energy utilities to develop integrated resource plans in an effort to

[1] For year 1990.

balance traditional "supply-side" resources such as new power plants, with "demand-side management" measures, including conservation and the shifting of power loads from peak-use periods to times of lower demand. The commission has also mandated that supply-side plans include alternative energy resources and address the social, cultural, and environmental impacts of various energy options. The state and local governments also participate in this process, along with private citizens.

The island's electric grids in Hawaii are not interconnected by submarine transmission cable, so market size; economies of scale of generation, transmission and distribution; and system reliability are critical issues for electricity delivery.

### Electricity Capacity

Below are specified the installed electricity capacity for each of the 4 islands in Hawaii State with utilisation of renewables for electricity generation.

Kauai Island

Installed Electricity Capacity on Kauai Island in 1999, by Source:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Thermal Plants | 95.3MW | 70.2% |
| Biomass | 36.5MW | 26.9% |
| Hydro | 4MW | 2.9% |
| Renewables Total | 40.5MW | 29.8% |

Source: Kaya, 1999b

Oahu Island

Installed Electricity Capacity on Oahu Island in 1999 by Source:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Thermal Plants | 1725.2MW | 95.8% |
| Biomass | 12.5MW | 0.7% |
| Municipal Solid Waste | 63.8MW | 3.5% |
| Renewables Total | 76.3MW | 4.2% |

Source: Kaya, 1999b

Maui Island

Installed Electricity Capacity on Maui Island in 1999 by Source:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Thermal Plants | 188.1MW | 74.4% |
| Hydro | 6.4MW | 2.5% |
| Biomass | 58.3MW | 23% |
| PV | 0.02MW | 0.008% |
| Renewables Total | 64.72MW | 25.508% |

Source: Kaya, 1999b

Hawaii Island

Installed Electricity Capacity on Hawaii Island in 1999 by Source:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Thermal Plants | 181.2MW | 76.5% |
| Hydro | 14.727MW | 6.2% |
| PV | 0.09MW | 0.04% |
| Wind | 10.93MW | 4.6% |
| Geothermal | 30MW | 12.7% |
| Renewables Total | 55.747MW | 23.54% |

Source: Kaya, 1999b

### Electricity Production

State of Hawaii

One objective for the State of Hawaii is the increasing use of indigenous energy supplies. During the period 1990-1997, overall renewable energy use for electricity generation did not increase, but the shares of the various resources changed, principally due to the decline in wind generation and sugar industry electricity. Other renewables, especially geothermal and municipal solid waste, largely filled the void.

Electricity Production for State of Hawaii by Source, in 1997:

| Source | Percentage of Total Production |
|---|---|
| Thermal Plants | 92.7% |
| Biomass | 1% |
| Geothermal | 2.3% |
| Hydro | 0.7% |
| Municipal Solid Waste | 3.2% |
| Wind | 0.1% |
| Renewables Total | 7.3% |

Source: Hawaii Energy Strategy 2000

Below are specified the electricity production for each of the 4 islands in Hawaii State with utilisation of renewables for electricity generation.

Kauai Island

Electricity Production on Kauai Island in 1997 by Source:

| Source | Generated Electricity (Million kWh) | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 351 | 78.9% |
| Biomass | 77 | 17.3% |
| Hydro | 17 | 3.8% |
| Renewables Total | 94 | 21.1% |

Source: http://www.state.hi.us/dbedt/ert/data/97kwhislsrc.html

Oahu Island:

Electricity Production on Oahu Island in 1997 by Source:

| Source | Generated Electricity (Million kWh) | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 7,299 | 95% |
| Biomass | 15 | 0.2% |
| Municipal Solid Waste | 371 | 4.8% |
| Renewables Total | 386 | 5% |

Source: http://www.state.hi.us/dbedt/ert/data/97kwhislsrc.html

Maui Island:

Electricity Production on Maui Island in 1997 by Source:

| Source | Generated Electricity (Million kWh) | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 1,042 | 86.9% |
| Biomass | 133 | 11.1% |
| Hydro | 24 | 2% |
| Renewables Total | 157 | 13.1% |

Source: http://www.state.hi.us/dbedt/ert/data/97kwhislsrc.html

Hawaii Island:

Electricity Production on Hawaii Island in 1997 by Source:

| Source | Generated Electricity (Million kWh) | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 731 | 71.1% |
| Geothermal | 229 | 22.3% |
| Wind | 17 | 1.7% |
| Hydro | 51 | 5% |
| Renewables Total | 297 | 29% |

Source: http://www.state.hi.us/dbedt/ert/data/97kwhislsrc.html

**Sources of Renewable Energy**

Hawaii's policymakers remains committed to further the utilisation of the state's renewable energy resources. It is estimated that in 1997 renewable resources displaced 3.2 million barrels of oil and reduced carbon dioxide emissions by nearly 1.7 million tons. Some renewable sources, such as biomass, geothermal, hydroelectricity, wind, photovoltaics and solar thermal for water heating are already cost effective in Hawaii. Over time, electricity produced from bioresidues from the sugar industry has declined with the closure of many plantations, but there have been gains in the use of geothermal, hydroelectric, and solar energy resources.

Biomass:

Historically, the largest local energy source has been biomass, which in 1980 provided 13% of the state's electricity. By 1997 that share had shrunk to 5.9%, and about 60 percent of this power production came from the combustion of municipal solid waste at Oahu's H-POWER plant, which began operating in 1989. This decline in biomass-fuelled energy production resulted from the dwindling of the primary fuel supply, bagasse, as sugarcane acreage decreased during the 1970s and 1980s.

Biomass remains a critically important resource, since it can serve both as a fuel for electricity generation and as a feedstock for liquid and gaseous fuels. The development of new production technologies that could make biofuels competitive in Hawaii has sparked a resurgence of interest in ethanol and methanol fuels. Other projects that could boost biomass use include the construction of a demonstration bagasse gasifier on Maui and state-wide research, into species of grasses and trees suitable for biomass plantations.

Geothermal:

The second most significant renewable source of electricity in the state is geothermal energy. Exploration into this resource began in the 1960s on the flank of Kilauea volcano. In 1976 a 6,450 feet deep (1,966 m) well was completed and flashed, and a demonstration geothermal power plant was constructed at the site in Puna, on Hawaii Island, with support from both public and private sector agencies. Operating from 1982 to 1989, the 2.5 megawatt facility proved the commercial viability of the geothermal resource, which at

676 degrees F (358 deg C) ranked among the hottest in the world.

Some 24,000 acres (9,800 ha) of land on Hawaii and Maui are now designated as "subzones" where geothermal development is authorised. Currently there is only one commercial geothermal power plant - the 25 megawatt Puna Geothermal Venture facility, which contributed roughly 22 percent of the electricity used on Hawaii Island in 1997. State monitoring of air quality surrounding the geothermal plant site is ongoing, and research continues on geologic history, groundwater chemistry, seismic events, and geothermal reservoir development potential.

In 1989 the state pursued ambitious plans to connect the major islands with a submarine cable to supply the main load centre on Oahu with geothermal energy from Hawaii. The project eventually proved to be uneconomical and was complicated with political controversy. The current use and further development of this resource remains controversial, given the concerns raised by some members of the community over safety, the health effects of geothermal emissions, Native Hawaiian rights, and land use conflicts.

Hydro:

Hydroelectricity is among the oldest electricity resources in the Islands with some plants dating back to the late 1800s. Hydroelectric plants in Hawaii use no dams; they are run-of-the-river installations and, as such, are intermittent electricity providers like wind and solar plants. State-wide there are 15 hydro facilities with capacities of 0.2 megawatt or greater. Most are owned and operated by sugar companies. The only utility-owned hydro plants are on Hawaii Island, as is the newest and largest plant, a 12-megawatt system operated since 1993 by the Wailuku River Hydroelectric Company.

Wind:

Hawaii also has excellent wind resources. Wind power plants with capacities of several megawatts each were installed at Kahuku on Oahu and at Kahua Ranch, Lalamilo, and South Point on Hawaii Island. The Kahuku development included the world's largest wind turbine at the time, with a generating capacity of 3.2 megawatts. Hawaii was among the leaders in the US, with the first commercial wind farms. However, first generation wind turbine technology was utilised, and equipment failures and high maintenance costs have affected the commercial success of wind power. Some machines, for instance at the Kahuku and Kahua sites, have since been removed from service, while repairs and renovations have temporarily reduced the output of others. Modern, state-of-the-art wind turbines including recent designs from Denmark and other European manufacturers could provide electricity less expensively than the models previously installed. At present, permits and contract negotiations are underway for two new 10 megawatt wind turbine installations on Maui and Hawaii.

Solar Water Heaters:

The most common renewable energy technology in Hawaii, and one most residents can utilise, is solar water heating. With more than 60,000 household systems installed, Hawaii boasts the highest per capita use of solar water heating in the nation. These systems provide approximately 3,122 billion btu of heat energy annually and contribute more energy than any other renewable energy resource state-wide except for biomass and solid waste. Most systems were installed in the late 1970s and early 1980s, encouraged by generous federal tax credits. When these credits expired, installations declined rapidly from several thousand per year to a few hundred per year state-wide. In 1989, the state increased its own tax credit to 35%; since that time installations have averaged over 1,000 systems a year. More recently, the state has initiated partnered private sector investment program for solar water heaters, through rebate incentives offered by the utility demand-side management programs. With the tax credits and utility rebates of up to $800 per solar water heater, the initial cost of these systems is reduced by 50 percent, and the number of systems installed per year has increased to between 4,000 and 5,000.

PV:

Another popular solar option, especially for residences in rural areas not served by the electric utility grid on Hawaii Island, is photovoltaics. There are also a number of grid-connected systems on residences, and several large grid-connected facilities on Maui and Hawaii Island that were installed as demonstration units. Within the last two years, the Mauna Lani Resort Hotel on Hawaii has installed two-100 kW roof-mounted photovoltaic systems to reduce their peak demand for electricity and showcase this environmentally benign technology in an appeal to the environmentally conscious traveller. Photovoltaic modules are commonly used in Hawaii by various agencies for emergency highway telephones, remote seismic-monitoring equipment, and navigational beacons. Hawaiian Electric Company has recently initiated a green pricing program for their customers who can sign up to pay extra to install photovoltaic systems on participating high school rooftops as part of an environmental education initiative.

Ocean Thermal Energy Conversion (OTEC):

The world's premier research site for the development of ocean thermal energy conversion (OTEC) technologies is at the Natural Energy Laboratory of Hawaii Authority facility at Keahole Point on Hawaii Island. OTEC utilises the temperature differences, which can range up to 40 deg F (22 deg C), between water pumped in from the warm ocean surface and the cold depths (2,000 feet [610 m] or greater) to generate electricity. The deep, cold water is also rich in nutrients and nearly pathogen-free, making it valuable for a broad range of aquaculture and agriculture enterprises. The cold water is suitable for chilled-water air conditioning systems as well.

Closed-cycle OTEC was first demonstrated in Hawaii by the Mini-OTEC barge that had a gross electrical output of 52 kilowatts. Experimentation continued through the 1980s, and ground was broken in 1993 at Keahole Point for a new plant to test improved components. An experimental open-cycle OTEC plant, rated at 210 kilowatts gross output, began intermittent operation in 1994. Open-cycle OTEC can produce desalinated water as well as electricity. The state is currently pursuing commercial OTEC at this location.

**Barriers and Lessons Learned**

The main factors affecting the commercial introduction of renewable energy technologies in Hawaii include the following:

► economic competitiveness,

► deregulation and restructuring of the energy industry,

► and environmental quality and siting controversies affecting project permits.

Given the current business climate, renewable energy projects developed by private investment capital must compete with utility projects. Contracts must be secured from the regulated monopoly utility, who is required to pay the project developer the utility's avoided cost for the energy and any capacity credit on deferred utility plant construction. This negotiation process has proven to be arduous and time consuming, and adds to the complexity of developing any renewable energy project. Since avoided cost of electricity in Hawaii is linked to the cost of oil, the primary fuel, projects tend to be uneconomical when oil prices are low as in recent years.

Hawaii, like many other states in the US and other countries world-wide, is considering introduction of more competition in the electric industry. The state's Public Utilities Commission has initiated a process to investigate deregulation of the industry, recognising that competition may serve to reduce the relative high costs for electricity in Hawaii. If competition is successfully introduced, unbundling will permit competition on the supply side, and all source bidding for generation resources will be possible. The state believes that societal benefits including renewable energy and energy efficiency can be preserved in a deregulated environment. A properly restructured industry can lead to more efficient allocation of resources, such as widespread use of real time pricing to send proper signals to market. However, the incumbent utilities, fearful of erosion of their markets, have vigorously opposed the introduction of competition except in very limited applications for new generation resources, and then only if they control the bidding process.

Perhaps the greatest impediment experienced within the state is the overall concern for the preservation of environmental quality and lifestyle. Hawaii's citizens can be very active in opposing new development largely because of an overwhelming conservation and preservation ethic within the state. This attitude is understandable, recognising that the beauty of the island environment is quite fragile, and is what draws visitors to the state and keeps residents there. Public opposition to new development is not limited to renewable energy projects, compatible land use concerns have stymied the development of conventional energy projects and other public facilities such as transportation systems, waste management projects, and prisons.

Funding for new technology demonstration and research and development has been harder to obtain, especially because of the state's current economic slowdown. Hawaii has had to rely on outside assistance to address pressing issues on its energy agenda. Actively seeking partnerships for technical assistance and funding from both the private sector and federal government has proven to be an effective means to leverage limited state resources. With renewable energy technologies in general and solar energy in particular, notable successes have been achieved in forming joint venture partnerships to stimulate private sector investment for the Pacific region that serve as a model for other regional programs.

Despite the difficulties and controversies, the state remains committed to its long-term goal of reducing reliance on imported fossil fuel. The commercial deployment of renewable energy technologies especially benefiting the island environment is a lynchpin of the strategy to achieve that goal.

**Energy Policy**

Hawaii State has a very comprehensive and detailed energy and renewable energy strategy – Hawaii Energy Strategy 2000.[2] This strategy also incorporates the Hawaii Climate Action Program.

Below are a very short description of overall objectives and some of the policies.

The State energy policy objectives are:

1. Dependable, efficient, and economical state-wide energy systems capable of supporting the needs of the people

2. Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased

3. Greater security in the face of threats to Hawaii's energy supplies and systems

To achieve the energy objectives it is among other things the policy of Hawaii State to:

► ensure the provision of adequate, reasonably priced, and dependable energy services to accommodate demand

► support research and development as well a as promote the use of renewable energy

The specific objectives of the Hawaii Energy Strategy 2000 are among others to:

1. Increase diversification of fuels and the sources of these fuels

2. Increase energy efficiency and conservation

3. Increase the use of indigenous renewable energy resources

4. Reduce greenhouse gas emission from energy supply and use

**Contact Information**

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**References**

Hawaii Energy Strategy 2000

Homepage of Energy, Resource and Technology Division, State of Hawaii (http://www.state.hi.us/dbedt/ert/ert_hmpg.html)

Kaya, 1999a

Kaya, 1999b

[2] The strategy Hawaii Energy Strategy 2000 (323 pages in total) can be downloaded at the homepage of Energy, Resources, and Technology Division: http://mano.icsd.hawaii.gov/dbedt/ert/hes2000/index.html

# San Clemente Island (USA)

### General Information

**Population:** n.a.

**Area (km$^2$):** 137

San Clemente Island is located off the coast of southern California, USA – approximately 135 km Northwest of San Diego. The island is the asset of the US Navy.

### Electricity Capacity

The islands electrical system is powered with 4 diesel generators, using wind energy to reduce the overall diesel system operating costs.

Installed Capacity by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 2,950 kW | 81.4% |
| Wind | 675 kW | 18.6% |

Source: Mckenna & Olsen, 1999 and Alpha Wind Energy

The first two turbines were commissioned in January of 1998 and the third turbine in July 1999.

### System Demand Statistics

System Demand Statistics in 1998:

| | |
|---|---|
| Peak daily demand (kWh) | 26,788 |
| Low daily demand (kWh) | 13,650 |
| Average hourly demand (kWh) | 846 |
| Average daily demand (kWh) | 20,320 |
| Average monthly demand (kWh) | 618,080 |
| Peak monthly demand (kWh) | 708,438 |
| Low monthly demand (kWh) | 578,025 |
| Annual fuel consumption (litre) | 2,074,240 |
| Energy/fuel ratio (kWh/l) | 3.58 |
| Demand growth (%) | 9.4 |

Source: Mckenna & Olsen, 1999

### Electricity Production

Electricity Production by Source in 1998:

| Source | Generated Electricity | Percentage of Total Production: |
|---|---|---|
| Diesel | 6,631,021 kWh | 89.4% |
| Wind | 785,938 kWh | 10.6% |

Source: Mckenna & Olsen, 1999

### Wind Energy

Wind Speed:

The annual wind speed is 6.1 m/s (measured from 1995 to 1998 on a 42.7m meteorological tower). The highest wind speeds are during winter.

Objectives of Wind Farm:

The purpose of the installation of wind turbines on the island were to:

► decrease the Navy's dependence on fossil fuels.

► to operate with the existing diesel power plant and provide equivalent or better power quality and system reliability than the existing diesel system.

► reduce the emission of  nitrogen-oxide and other pollutants.

Wind Farm Configuration:

The wind farm consist of 3 NEG Micon M700-225/40 kW wind turbines, each with 29.8 meter rotor diameters and 4-section towers providing a hub height of 30 meters. Additionally an indoor switchgear installed on the turbine site, a remote SCADA system located in the control room of the power plant, and a system integrated load management system.

Environment:

When the turbines where erected, careful consideration was given to impact on the island's sensitive environment. The Navy worked close with the U.S. Fish and Wildelife Service to prevent disturbing the federally listed island night lizard. Measures were also taken to protect raptors from the turbines. Archaeological sites were clearly marked to prevent disturbances. To keep impact to a minimum, the project area was kept as small as possible.

Financing:

The turbines were funded through the Department of Energy (DOE).

Performance:

The wind farm maintains an average availability in excess of 98% and meets wind penetration up to 75%.

Economics:

Using two 225 kW turbines, the wind energy costs of energy of US$0.142/kWh helps reduce the wind-diesel hybrid system costs of energy from the baseline US$0.476/kWh to US$0.461/kWh. This reduces system costs of energy by 3.2%. The payback period is 6.5 years, the internal rate of return 14.4%.

Project Highlights:

The island presented several logistical and technical challenges due to the need for barge transportation of materials and construction equipment to and from the island and the requirement for a system integrated load management system. Despite these challenges, the project was commissioned within budget and ahead of schedule.

Future Expansion:

The long term objectives of the U.S. Navy for San Clemente Island (SCI) are to install about 8 MW of wind capacity and to develop a pumped-hydroelectric storage system, using the ocean as the lower reservoir.

There has also been proposed to make a seawater desalination plant for the island using wind turbines. If funded, two additional wind turbines and the desalination plant will make San Clemente Island fresh water independent. Currently, the island's fresh water supply is barged from San Diego at the rate of nearly 14.5 millions gallons per year. The potential annual savings from a wind-powered desalination system could be nearly US$478,000 per year. In addition, by generating their own fresh water, island managers could reduce the number of trips made by diesel-powered tugs.

**Contact Information**


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**References**


Mckenna, & Olsen, 1999

Information provided by Alpha Wind Energy

News Release from Naval Facilities Engineering Service Center

# St. Paul Island (USA)

## General Information

**Population:** 700

**Area ($km^2$):**

The island of Saint Paul is one of he Pribilof Islands, located north of the Aleutian Chain in the Bearing Sea in the North Pacific.

## Electric Capacity

Installed Electricity Capacity by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 1,300kW | 85,2% |
| Wind | 225kW | 14.8% |

Source: Davidson, 1999

A 1MW diesel plant powers the island's main grid.

A stand-alone wind-diesel system (1 x 225 kW wind turbine and 2 x 150 kW diesel) powers a company-owned commercial building complex.

## Stand-alone Wind-Diesel System

Background:

Tanadgusix Corporatoin (TDX) is an Aleut Native Alaska Village Corporation. The company is active in the commercial real estate, hotel, eco-tourism, fish processing, and environmental engineering industries.

The cost of importing diesel fuel to St. Paul Island combined with the operating costs of the plant results in some of the nation's highest power tariffs. According to TDX, commercial power rates on the island are close to US35 cents/kWh, high enough that operations ship in fuel and containerised gensets to power their seasonal loads rather than purchase additional power from the main grid.

Since 1994, TDX has worked to add wind energy production to the island's diesel generating system to offset fuel use in general, to lower the operating costs of the island's utility and to reduce the pollution that is caused by diesel fuel use at the fish processing plant.

In 1994 Saint Paul was investigating its options for modernising the island's generating systems. TDX developed a proposal that included the construction of a wind farm on 50 acres of company land on the island. The corporation would have provided a project equity investment and predicted electricity priced below 15 cents/kWh. Despite the company's efforts, the island chose in favour of an opportunity for bond financing the existing diesel system and the wind project was put on hold.

TDX began looking for other means to employ wind energy on the island. TDX would prove the viability of wind power by implementing a smaller scale project designed to serve one of its own commercial loads. TDX hoped by demonstrating wind power technology at a low costs, reliable generating source at its own financial risk, there would be motivation to discuss a larger, utility interconnected project.

Therefore to demonstrate the viability of wind energy, TDX decided to implement a wind project at a TDX building complex known as POSS Camp as a stand-alone system. In other words, TDX permanently disconnected POSS Camp from the island's utility distribution line and constructed a hybrid power plant capable of 100% availability. The system is designed to provide this level of service, regardless of wind or weather conditions, without utility backup.

The system went into operation in March 1999.

Wind Regime:

Wind conditions on the island are ideal for wind energy. The average annual wind speed is in excess of 8 m/s, a velocity consistent with the requirements of commercial wind power generation. The wind come from the same north-east direction over 70% of the time in a relatively smooth, non-turbulent flow.

Project Configuration:

The major components include:

► one 225 kW Vestas wind turbine

► two 150 kW diesel generators for back up during low wind periods

► one waste-heat hot water heating system

The waste heat driven hot water heating system is constantly charged by excess wind power and/or engine heat recovery. By using the system's dump load for hot water-based space heat, TDX could significantly reduce its annual 30,000 gallon, US$50,000 purchase of diesel heating fuel.

By dumping the often erratic fluctuations of the wind turbine's power output during high wind periods the system achieves its required continuos power quality. Application of the second diesel engine generator set achieves the required redundancy and reliability.

Organisation:

The approximately US$ 1 million power station was financed 100% by TDX.

TDX Power:

TDX has created a subsidiary, TDX Power. TDX Power's business plan will be to develop, finance, own & operate wind farm, hybrid and biomass projects in appropriate Alaskan communities.

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# Fiji

## General Information

**Population:** 823,376 (2000 estimate)

**Area ($km^2$):** 18,376

Fiji is situated in the southern Pacific Ocean, located approximately 3,100 km north-east of Sydney, Australia, and approximately 5,000 km south-west of Honolulu, Hawaii.

Fiji consists of more than 800 islands and islets. About 100 of the islands are inhabited.

The two largest islands, Viti Levu and Vanua Levu, comprise more than 85 percent of the total area.

Below are specified population and size for the two largest islands:

| Island | Pollution[1] | Size ($km^2$) |
|---|---|---|
| Viti Levu | 340,561 | 10,429 |
| Vanua Levu | 129,154 | 5,556 |

## Introduction

Fiji has always relied on imported petroleum products for all its transportation needs as well as for electricity generation and industrial uses. But since 1983, the major island, Viti Levu, has been provided with electricity from a hydropower station.

Energy for domestic cooking and heating has been dominated by biomass, which has also provided energy to the sugar mills in Fiji through bagass. Biomass also provides energy for commercial, industrial and agricultural use.

The major energy sources are biomass, hydropower and petroleum products.

## Electricity Capacity

Installed Electricity Capacity on Viti Levu Island by Source in 1999:[2]

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Diesel | 60 MW | 44% |
| Hydro | 76 MW | 56% |

Source: Narayan, 1999

[1] 1986.
[2] As of August 1999.

Installed Electricity Capacity on Vanua Levu Island in 1999:[3]

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Diesel | 1.04 MW | 56.5% |
| Hydro | 0.8 MW | 43.5% |

Source: Narayan, 1999

The responsibility for electricity generation, transmission and distribution in Fiji is vested with the Fiji Electricity Authority (FEA). FEA is a government owned organisation.

## Electricity Production

Electricity Production on Fiji by Source in 1997:

| Source | Electricity Production (billion kWh) | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 0.110 | 20.4% |
| Hydro | 0.430 | 79.6% |

Source: http://www.eia.doe.gov/emeu/world/country/cntry_FJ.html

## Renewable Energy Development Program

It has always been in the interest of the Fiji Department of Energy (DOE) to promote the use of renewable energy resources and exploit these resources to provide high quality energy. In 1996, the Fiji Government announced energy as a priority in its development plans. This not only boosted the role of the DOE but also enhanced its Renewable Energy Development Program (REDP).

The primary objective of the REDP is to research into the various indigenous renewable energy resources and assess its technical and economical viability for development. This is in the perception of reducing the use of imported and expensive non-renewable fuels. However, prior to development of any renewable resource, DOE considers it important to have a collection of the relevant data for analysis. This allows technical and economical assessment to be carried out effectively.

A significant percentage of Fiji's rural population is without electricity and do not have access to the national electricity grid. This made it necessary for DOE to develop the REDP to research into the viability of the renewable resources for electricity supply. Although there are a wide range of local renewable resources, those of current concern

[3] As of August 1999.

to DOE include solar, hydro, wind, biomass and geothermal.

The Renewable Energy Development Program has enabled the DOE to explore and exploit its indigenous renewable resources. The program has also enabled the study of the various technologies available in the market and exploring their viability in the environment. The success of some of the pilot projects has lead to incorporating in the renewable energy policy the resource and technology as an option for electricity generation. The not so successful pilot projects has prompted DOE to further investigate into the technology options available to utilise the renewable resource in the most efficient manner.

The DOE intends to continue its REDP with the intention of offering new sources of energy and technology to the country and further reduce the reliance on importing costly non-renewable fuels.

**Solar Program**

Fiji has considerable sunshine and it can be utilised to generate electricity at low operating and maintenance costs and being environmentally friendly make it an attractive option for electricity supply. As a result there is an increase in regional research and demonstration of PV projects and DOE has placed PV as a rural electrification option in its Rural Electrification Policy.

The DOE has in the past installed various PV demonstration and trial projects including water pumps, video and television. The success rate of performance for most of these solar applications, in particular the water pumps, was poor. These systems were poorly maintained and as a result are not operating. However, the trial projects for the solar video and TV has proven successful in the rural areas.

The provision of basic lighting has been the main focus of the solar energy programme. Solar lighting projects consisted of the supply of 2-11W lights and 1-7W night-light. This had proven to be sufficient in the past. However, in 1996 a rural survey was carried out on a village with an existing solar system, which identified a demand for a bigger system that could allow for the use of electrical appliances.

The most recent major PV project has been the Photovoltaic Electrification of Naroi, which is a F$ 1 million dollar French government funded project in Fiji's Lau Group of Islands. The village of Naroi on the island of Moala in the Lau Group is electrified using renewable, non-polluting solar generators. The DOE provided locally sourced materials, including treated wood poles and transport of the equipment to Moala. Approximately 170 households have been equipped with high efficiency, solar powered lighting systems and prepayment meters. The solar generators used for Naroi have an estimated life span of over twenty years with battery replacement required every eight to ten years.

**Hydro**

Fiji Islands group is well endowed with water systems both large and small scale. These water systems are fed by heavy rainfall, due to the mountainous topography of Fiji's volcanic islands.

The introduction of the hydro programme focussed on the following objectives:

► to assess all potential mini/micro, hydro sites throughout Fiji and determine their feasibility

► to rank all potential sites within Fiji which would facilitate a more detailed examination and subsequent development.

► to ascertain the viability of the sites that have been identified above.

► to prepare a pre-feasibility study report for identified sites, which have undergone the long-term monitoring programme and has proved viable in terms of the hydrology of the site.

From provisional ranking, the long term monitoring of at least two years is undertaken to determine the consistency of the available data.

Hydropower has received general recognition in Fiji and given the importance for rural electrification and the availability of potential hydro sites around the country, hydropower is also incorporated into the renewable energy policy (1993) as an electrification option. There are 7 micro hydro projects in operation in Fiji. The size of these projects range from 3 kW to 100 kW.

The most recent hydro project is Muana Hydro scheme. This project was funded by the

Korean Government, through the Korea International Corporation Agency (KOICA), from a grant of $US 200,000 with local costs met by the Government of Fiji.

The project is for three villages in the Northern Coast of Vanua Levu. The three villages have approximately 136 households with a population of approximately 600. The three villages also host a primary school, a health center, groceries shops, community halls etc. The project design capacity is 30kW.

**Biomass**

Fiji has considerable biomass resources - forests, coconut husk, bagasse, sawmill waste, rice wastes to name a few, which can be used as fuel for industrial processing as well as for steam co-generation plants in rural areas.

Bagasse:

Fiji Sugar Cooperation (FSC) has historically been using bagasse as fuel in the steam co-generation plants in all of their mills at Lautoka, Rakiraki, Ba and Labasa. FSC generates significant amount of electricity in these mills for their use and the surplus is sold to FEA.

Bagasse is derived from the processing of sugar cane and the four FSC sugar mills crush an average of 3.64 million tonnes of cane annually.

Wood:

An Energy survey conducted by DOE revealed that wood contributed 18% of Fiji's energy supply in the period 1988 - 1992 and approximately three-quarters of the wood supply is consumed by the household sector for cooking.

Wood supply for household use is largely informal. Most rural homes collect their own wood. In areas deprived of forest and fuel wood supplies, wood is obtained from vendors and saw millers.

Wood is also used in the industrial sector for raising steam. A pine wood sawmill at Lautoka is perhaps the single largest producer and user of waste wood. Production of timber and chips at Drasa from plantation pines results in 30,000 tonnes of fuel quality biomass waste produced annually. The sawmill uses approximately half of this wood waste for cogenerating electricity (3 MW) and steam. The remainder of the wood waste is accumulating adjacent to the factory. Efforts are continuing to find a suitable use for this energy resource.

Institutional Wood Stoves:

In the early nineties, the DOE carried out a research on smokeless and efficient wood stoves. As a result a more comprehensive design on woodstoves is currently being used in Fiji. The Foundation of the People of the South Pacific (FSP), a non-governmental organisation is playing the leading role in the construction and dissemination of institutional wood stoves to boarding schools throughout the country. However, the DOE has continued in assisting FSP on the construction of the stoves. Currently, attempts are under way to disseminate the knowledge on institutional wood stove construction to other Pacific Island Countries.

Municipal Waste:

Disposal of municipal waste is an increasing problem for all urban areas. Fiji's major urban areas produce waste in large quantities and energy generation from this resource, specially waste incineration, is an option DOE see worth evaluating.

To determine the volume of waste entering the dump each day DOE installed a weighbridge at the Lami dump in 1995. Sufficient data has been collected over a period of two years.
In January 1997, to determine the composition of the waste entering the dump DOE engaged the services of the University of the South Pacific Chemistry Department (USPCD). This project included the sampling and seperation of the waste entering the dump and analysing the samples.

Steam Plants:

In 1987 a steam co-generation plant was installed in Navakawau village in Taveuni which provided electricity for household lighting and heat for copra and kava (yagona) drying. The plant included a combined 10kW electricity generator and a copra drying plant using steam generated from biomass.

Currently the steam plant is in urgent need of overhaul and repairs. There are also plans to relocate this plant as the current village has not maintained the steam plant properly and supply of fuel has been low.

Another steam cogeneration plant is installed in a private estate in Wainiyaku, Taveuni. The estate owners privately own the plant.

Biogas Digesters:

In 1996, DOE, in collaboration with Ministry of Agriculture, embarked on a pilot Biogas project programme in Fiji. So far DOE has successfully installed 15.8m$^3$ biogas digesters at two piggery farms and one diary farm. The biogas is used as a fuel for domestic cooking and heating water at the dairy farm.

**Wind**

In Fiji wind technology has been utilised in a very small scale and until recently, the winds of Fiji have not to-date been the subject of any systematic assessment for determination of their potential to generate electricity.

In 1991 DOE began installing wind monitoring stations in order to determine the wind regime in the country. The collection of data was necessary to determine and identify the viable sites for potential installation of wind farms to be connected to the national grid as a supplementary source of energy.

An important feature of this program has been the dissemination of data collected and discussions with interested wind farm developers. The dissemination of data has led to the presentation of proposals by Independent Power Producers (IPP) towards the utilisation of this renewable resource.

A total of five wind monitoring stations exist around Fiji with three located along the southern coast of Viti Levu while two have been installed in Vanua Levu. Raw hourly data have recorded wind speeds ranging from light to strong winds (2 - 15m/s).

Wind and solar radiation data has been collected for two years at Nabouwalu Government station till July, 1997. In 1997, DOE in conjunction with Pacific International Center for High Technology Research (PICHTR) installed a small hybrid power system in Nabouwalu Government Station in Vanua Levu.

A financial aid of F$ 800,000 was provided by the Ministry of Foreign Affairs of Japan (MOFA) to PICHTR for the purchase of the hardware and equipment for this project. The local costs totaling approximately F$ 180,000 for civil and road works, construction of power house, purchase of transformers, electrical cables and accessories was met by DOE.

The hybrid system consists of 8 x 6.7kW wind turbines, 40 kW solar system and 2 x 100kW stand-by diesel generators. The Nabouwalu Government Station includes a Government hospital, Post Office, Provincial Council building, Agriculture and Fisheries Department, Public Works Department depot and its staff quarters, Police station and its staff quarters and three shops, and other Government Departments, altogether totalling approximately 100 consumers.

The Nabouwalu Village Hybrid Power System has been optimised to produce 60% of the electricity from renewable energy resources (wind and solar) and the balance with diesel generators.

**Geothermal**

The DOE is involved in the investigation of the extent of Fiji's geothermal resources for future energy planning and supply purposes in Vanua Levu. The objectives of the geothermal programme are to determine:

- whether exploitable geothermal fields exist in Savusavu or Labasa,
- the cost of exploiting these fields for electricity generation/process heat on Vanua Levu,
- the comparative cost per mega-watt-hour of geothermal electricity generation with other generating options on Vanua Levu and,
- to promote the development of the geothermal resource by inviting BOO/BOOT schemes.

Fiji's geothermal resources have the potential to be developed to supplement Fiji's presently predominant Hydro Electric Power (HEP). This could only be made possible once the technical and economic viability of geothermal resource is assessed and proven. Geothermal is particularly important for Vanua Levu where the prospects for a significant sized HEP potential is severely limited.

Surface study results have indicated that the Savusavu prospect, which has reservoir temperature near 250C, can provide heat to enable the generation of approximately 25 MW of electricity. The Labasa prospect's reservoir temperature is close to 130C and can provide process heat.

To date, all geophysical surveys have been completed and the next stage will be deep drilling to verify the theoretical findings and the subsequent development of the resource.

**Wave Energy**

The wave power generation data collection programme began in Fiji in 1990. A report on the data collected was prepared. In 1999, DOE in collaboration with South Pacific Applied Geoscience Commission (SOPAC) planned to carry out additional work on ocean and wave energy in Fiji.

Currently, SOPAC is discussing with Norwegian Agency for International Development (NORAD) the possibilities of analysing the cost/benefit of generating electricity from sea waves as compared to the traditional option of generating electricity using diesel fuel. A detailed project proposal will then be prepared for submission to NORAD in 1999.

Meanwhile, following DOE submissions for a wave energy project, Fiji Mission to the United Nations has secured funds for a 5 kW wave project in Fiji through the Trust Fund on New and Renewable Sources of Energy of the United Nations. DOE is currently liasing with the consultants (Ocean Power Technologies, USA) for the implementation of this project.

**Overview of Renewable Energy Potential**

Renewable Energy Resource Potential on Fiji:

| Source | Potential |
|---|---:|
| Solar | Good Resource |
| Wind | Good Resource |
| Biomass | Excellent Resource |
| Hydro | Excellent Resource |
| Geothermal | Excellent Resource |
| OTEC | Good Resource |
| Wave | Good Resource |

Source: Ellis & Fifita, 1999

**Policy**

There is a national renewable energy policy from 1993.

The Fiji Government via its Department of Energy promotes, through energy policies, the use of indigenous renewable energy resources and the efficient use of energy. Its aim is to reduce the level of dependency of Fiji on imported petroleum products and to reduce the country's energy costs.

On the energy demand side, the measures mainly involve energy management and conservation of energy which consumers themselves may adopt to improve the efficiency of the energy systems they use.

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# Isle of Pines (New Caledonia, France)

## General Information

**Population:** 1,700

**Area (km$^2$):** 141.4

New Caledonia and its Dependencies - the Isle of Pines, the Loyalty Islands, the Chesterfield Islands, and the Huon Islands - is a overseas territory of France, and situated in the south-western Pacific Ocean, east of Australia.

Isle of Pines is located approximately 50 km South East of the capital Nouma on the main island of New Caledonia.

## Electricity Capacity

Installed Electricity Capacity by Source in 2000:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 1,500kW | 90.4% |
| Wind | 160kW | 9.6% |

Source: VERGNET S.A. 2000

Load is from 350 kW average to 500 kW peak.

## Wind Farm

A wind farm consisting of 3 x 60kW VERGNET wind turbines was commissioned in September 1999.

VERGNET supplied a turnkey wind farm connected to the diesel grid with distance operating.

The hybrid wind/diesel power system was elaborated to cope with the increasing demand on the island, particular since the opening of a resort.

A computer system monitors the turbines and relays information to the diesel plant enabling the power supply to switch automatically between the two separate systems.

The diesel plant, which operates permanently, allows continuos energy supply and maintains tension and frequency.

To start production, the turbine blades need a minimum of 5 m/s wind. The turbines stop if the wind exceeds 35 m/s. If a cyclone or a tropical depression approaches, the turbines can be pulled down to the ground.

Main issue is that there is no crane on the island so the VERGNET's "self-erecting" turbines were utilised.

Wind Speed:

Wind monitoring was made in 1996-97. The wind speed is 7.5 m/s on the site.

Estimated Production:

The annual wind output is guaranteed by VERGNET for five years at a minimum of 335,000 kWh/year , which is approximately 15% of the consumption on the island.

At its maximum output, the power generated by the turbines is capable of providing more than 25% of the power requirements for the island's 1,700 inhabitants and its hotels.

Organisation:

The ownership is private – Société Neo-Caledonienne d`Energie (ENERCAL) – is the owner.

Operation and maintenance is locally by ENERCAL and SOCOMETRA (VERGNET's local partner).

Economics:

A period of three to five years has been estimated before determining the actual economic benefits. In the meantime ENERCAL is satisfied with the savings on fuel transportation costs and the turbines' relative low maintenance requirements, which are sufficient for the project to go ahead.

Costs:

The total costs of the wind farm were approximately US$550,000.

Future Projects in New Caledonia:

In New Caledonia, VERGNET S.A. carries out studies on two islands regarding possible wind generation:

► on Lifou Island – part of the Loyalty Islands – for a wind-diesel plant with 900 kW wind capacity

► on Ouen Island for a autonomous village wind power system with 30 kW capacity

The two studies are made on behalf of Electricite et Eau de Caledonie (EEC) – the second electricity utility on New Caledonia.

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### References


Information provided by VERGNET S.A.

Pacific Power, 1999

# King Island (Australia)

### General Information

**Population:** 1,800

**Area (km$^2$):** 1,250

King Island is located 85 km off the north-west tip of the Tasmanian mainland.

### Electricity Capacity

Installed Electricity Capacity by Source in 1997:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Diesel | 4,800kW | 86.5% |
| Wind | 750kW | 13.5% |

Source: Hydro-Electric Corporation, 1997

Varying demands result in operating loads ranging from night-time minimum of 850 kW to a daytime maximum of 2,700 kW.

The island is not connected to other electricity grids.

### Electricity Production

Electricity Production by Source in 1999:

| Source | Percentage of Total Production |
|---|---|
| Diesel | 80% |
| Wind | 20% |

Source: http://www.hydro.com.au/windpower/index.htm

### Huxley Hill Wind Farm

A 750 kW grid connected wind farm, consisting of 3 x 250 kW Nordex Balke-Dür wind turbines, was commissioned in February 1998.

Background:

The Hydro-Electric Corporation (HEC) studied wave, wind, hydro and pumped storage options for supplementing the existing diesel generators. Wind power was found to be clearly the most favourable option.

The project will give HEC an opportunity to review wind technology and its application in remote island-diesel power systems and possible future large mainland Tasmania wind farms.

The wind farm take advantage of the Roaring Forties, the prevailing westerly wind that circle the earth's high southern latitudes.

Site:

Several different locations were studied on King Island, but the best site was determined to be the crest of Huxley Hill. There, the axles of the turbine blades, sitting on top of their 30 metre tall towers, are about 130 metres above sea level where the average annual wind speed is measured at 9.2 m/s.

Technology:

The three wind turbines demonstrate how wind and thermal generation technology can be used together efficiently.

Advance control systems manage both the wind farm and the diesel-powered thermal station to ensure the assets are used to maximise the benefits to the environment and minimise the use of diesel while providing reliable, high quality electricity. HEC is monitoring the control systems to see whether or not performance can be improved further.

Dump Load:

A dump load is connected to the low voltage part of the wind farm feeder. The dump load consist of four heating elements (35 kW, 70 kW, 140 kW and 280 kW) mounted in a cabinet, cooled by fans. The dump load can be controlled in steps of 35 kW from 0 to 525 kW.

Environmental Benefits:

Emission of carbon dioxide has been reduced by up to 2,000 tons a year on the pre-1998 figures.

The HEC saves hundreds of thousands AU$ each year in diesel costs for the island's thermal power station.

Organisation:

The turbines is funded by the Hydro-Electric Corporation out of the organisation's electric tariff income.

Hydro-Electric Corporation owns the turbines – ownership is thereby public since Hydro-Electric is owned by State Government.

Regarding operation and maintenance a contract is made with a private firm for the first three years of operation.

### Policy

There is not an overall strategy for renewable energy development on King Island, but HEC has a renewable electricity and electricity efficiency strategy.

### Contact Information

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| Internet: | http://www.wind.com.au/ |

### References

Homepage of Hydro-Electric Corporation (www.hydro.com.au)

Homepage of Sterling Wind (www.wind.com.au)

Information provided by Hydro-Electric Corporation

# Kiribati

## General Information

**Population:** 75,000

**Area (km$^2$):** 746

Kiribati is situated in the central Pacific Ocean, about 4,000 km south-west of Hawaii. The islands extend about 3,900 km from east to west and from north to south they extend about 2,100 km (straddling the equator).

The country consists of 33 islands of which 17 are inhabited. Kiritimati (also called Christmas Island), one of the Line Islands, occupies 609 km$^2$ and it thus accounts for the majority of the country's land area.

Kiribati is sub-divided into three main groups:

1) the Gilbert group: a chain of 17 atolls spread over 680 kilometres in the west which includes Tarawa, the seat of Government

2) the Phoenix group: a cluster of 8 atolls lying about halfway between the Gilbert and Line groups

3) the Line group: a chain of 8 atolls spread over 2,000 kilometres, located some 3,000 kilometres east of the Gilbert group. It includes Kiritimati Island

## Introduction – Largest PV Program in the Pacific Islands Region

In end of 1999 the European Union (EU) approved a US$ 3.57 million aid package to fund the installation of photovoltaic (PV) throughout the Gilbert Islands group. The project will be the largest PV program in the Pacific Islands Region.

The project will start in 2000 and end in 2005.

Background:

The background for this decision is an evaluation of 250 PV systems for rural households in the outer islands installed and maintained by a solar utility. These PV systems were funded by the EU Lomé PV Follow-up Programme in 1995.

The evaluation found that after 4½ years 95% of the installations was still functioning.

Objectives of the Project:

The overall objectives of the project is to:

improve living standards on outer islands and reduce migration to the main island

The project purpose is to:

provide a sustainable source of electricity for rural households and community centres

Breakdown of Type of Activity:

| Activity | Percentage of Total Project Costs |
|---|---|
| Construction/Infrastructure | 3% |
| Supplies of equipment/Inputs | 64% |
| Technical assistance, incl. studies | 21% |
| Training | 6% |
| Other | 6% |

Source: DG Development, 1999

## Why Solar Energy for Rural Electrification?

Alternatives Sources of Energy for the Rural Areas:

Kiribati had been relying heavily on imported energy and will continue to do so in the years ahead. At this time the choices for power generation is limited to two sources: solar and fossil fuel powered generator.

In spite of the abundance of solar energy in Kiribati, its use on the present state of development is limited to certain areas. Fossil fuel generation will continue to be the main base of power generation for Kiribati especially to support energy demand of South Tarawa where the average peak demand is at 1,998 kilowatts. To use solar energy in its present development state as substitute to meet the energy demand on South Tarawa will not be a practical option. However, there is potential for the use of the solar PV system in the rural areas where the average demand of household is less than 1 kilowatt.

The application of PV solar system in Kiribati is mainly concentrated on social activities rather than in support of direct commercial economic developments. The initial area of concentration of the PV Solar system has been for the provision of efficient electric lighting services in the rural areas of Kiribati. Recently the need has expanded to the connection of radios, cassette players etc. The changes are understandable given that Kiribati can not distance or shield it self from developments going on around it. Energy demand will increase as the people are exposed to these influences.

Environmental Issues:

With the fragile land and the enclosed reef, there is concern that energy production will have negative effects on the environment. The possibility of fuel and lubricating oil spills contaminating both the ground water and the reef is a concern together with the noise and the green house gases emitted from the diesel engines. The disposal and recycling of used oil and lead from batteries are major environmental concerns in Kiribati. At this time, the used oil returned to the Kiribati Oil Company from the public utility company (PUB) and other major users are send back to Mobil in Fiji for recycling.

In the case of solar PV system, the only environmental concern is the disposal and recycling of used batteries. However, GNB a battery manufacturer in New Zealand has indicated its willingness to recycle used batteries. Therefore, from an environmental point of view, solar energy for electricity production for rural household electricity needs has many advantages over other alternative sources of energy.

Cost Issues of Solar PV System:

Looking at the current electricity demand of the rural Kiribati citizens, the solar PV system at present offers the most economical system to provide the level of power desired.
The cost advantages of using the solar PV system is that:

(a) it does not require construction of an interconnecting grid;

(b) having little potential for environmental damage (provided a means for recycling failed batteries is included);

(c) requiring a predictable one-time capital investment with low operating and maintenance costs;

(d) finally being modular the systems can be specifically sized to fit the needs of individual households.

Although not directly related to costs, other advantages of PV over diesel for rural Kiribati include the continuous availability of power rather than a few hours per day which is all that can be afforded with a diesel system to reduce its high operational cost. The fact that each solar PV system is independent means that the failure of one system has no effect on any other while the failure of a component in a diesel system often leads to a loss of power to many if not all customers.

**PV Electrification of Rural Areas**

The Solar Energy Company:

The Solar Energy Company (SEC) was established in 1984 by the Foundation for the Peoples of the South Pacific (FSP), an U.S. based NGO, using USAID funding. It was organised as a private, limited corporation with a responsibility of selling out solar products to private individuals as well as Government and non-government organisations. Its original charter was to act as a retail outlet for solar products and to provide technical assistance, if needed, for the installation and maintenance of solar systems. The company's main income comes from the sales of solar products to private individuals as well as Government and non-government organisations. The sale of solar products was not promising to the company and therefore it became necessary to expand the Solar Energy Company activity to include the electrification of the outer islands.

Past Experiences:

Solar and diesel/benzene powered generators were the only sources of power commonly used in Kiribati. In the early 1970s diesel generators were very popular in the rural area of Kiribati. Its use was mainly for lighting and because of this the generators were only run for a couple of hours every night. The use of solar PV systems started between the 1970s and 1980s and used mainly for cassette player, FM/AM and CB radios and lighting.

Solar PV system was new at that time and its use was not widely known. In this connection the Energy Planning Unit (EPU) of the Ministry of Works & Energy was assigned with the responsibility of providing technical assistance to the company and the promotion of the use of solar PV systems through aid funded projects. Within this understanding the SEC confined its activity to the sales of solar products while the EPU, acting as the co-ordinator of energy activities in Kiribati, promote the use of solar PV system in the country by identifying projects that utilised solar energy and let the SEC implement them. Consequently, the EPU considered it most appropriate to improve the technical capability of the SEC together with island council technicians/mechanics.

In an effort to improve the SEC technical capabilities in maintaining and installing solar PV systems, the company was invited to take part in training courses conducted by South Pacific Institute for Renewable Energy (SPIRE) in Tahiti. To further improve reliability and to increase people's awareness on the rural areas on the use of solar PV systems, training courses were held on Tarawa in 1986 and 1988 for the rural area population. The objective of the course was to train people in the rural area on maintaining and installing solar PV systems, together with SEC technicians. In doing this, two participants from each of the island in the Gilbert group were invited to attend the courses. The requirement for the participants were that one of them should be a mechanic or technician employed by the island council and the other from the private sector. The rationale being that the island council worker will be responsible for maintaining government solar powered projects while the other participant attend to requests from private users of solar PV systems. With this in place, it was hoped that the reliability and acceptance of solar PV systems in the rural areas would improve. Despite these attempts the popularity of solar system declined as many people considered it unreliable and did not last long.

In an attempt to determine the reasons for the declining in sales and to provide data on how to proceed with further PV implementation, the SEC through the EPU requested the Forum Secretariat Energy Division (FSED) in 1990 to fund a country wide survey of rural PV system users. The purpose of this survey was to determine the cause of failure and non-acceptance of the Solar PV Systems. The emphasis on the survey was put on systems sold by the SEC to private individuals. The survey was carried out in all villages of the rural areas of the Gilbert Group, where the PV users could be found.

From the survey, it was found that 270 solar systems have been installed in the rural area. Of the 270 PV systems, about 90% were only marginally operational or not in use at all. It was also found that the main problems were:

► About 100% of the systems were undersized and had not been properly maintained apart from the replacement of defective components. Battery life was shorter than anticipated. Most components were never cleaned and had been damaged by insects and rust.

► 50% of the systems had been installed without a controller thus shortening battery life. The controller in a small system is a required to prevent overuse of the battery.

► 48% of the installations had serious wiring deficiencies, usually in the form of twisted connections or wires that were too long for their size thus resulting in high voltage drop.

► 43% of the systems had replaced the original deep discharge batteries with automobile batteries having inadequate capacity and a short life expectancy.

► 16% of the systems received minimum charging because of poor orientation of panels.

► 13% of the systems were placed in locations where panels were shaded most of the time.

► Many users had replaced the original high efficiency fluorescent lights with automobile headlights or taillights when the fluorescent tube failed, making the system consume more power than originally designed to. Others added CB radios and other appliances as well as using the systems for longer hours making the system under sized.

In the light of the above people were discouraged to purchase a solar PV systems, as they had known it to be unreliable and expensive. It was concluded that the concept of selling out solar PV system without any technical back up service was not a practical approach. Not only that but it was also found that the majority of the people using solar can not afford to purchase the right parts and therefore they tend to use parts they can get at either minimum cost or at no cost at all.

**The New Challenges to the Rural Electrification Concepts**

<u>The Utility Concepts</u>

Following the survey it was clear that the present approach was not a success in the electrification of the rural areas and as such an alternative means needed to be identified to further improve the solar-based rural electrification in Kiribati. In this regard, assistance was sought from SPIRE to advice the Kiribati Government on ways of rectifying the situation. SPIRE was requested here because it has successfully electrified some islands of French Polynesia using solar PV systems. The result of the study was a recommendation to promote a service-oriented approach based on a utility concept. This requires a back up service and users charged a fee for the use of the system with the system owned by the company looking after the rural electrification program. The SEC was thereby selected to shoulder this responsibility since it was the only Government owned company dealing with solar.

To introduce the utility concept, it was recommended that:

► The system should be owned and maintained by the SEC. Appliances and house wiring after the battery are owned and maintained by the user.

► To set up rural electrification district with not less than fifty households. The district should be of a sufficient size to allow proper servicing of the systems by a single SEC employee who would be designated as a field technician. It was considered that a single field technician could properly maintain up to 125 systems where this was based as the maximum size of a district. If more than 125 systems could be installed in a village, it would be split into two districts provided the household in the second district is not less than 50.

► Users to sign a contract in which they should agree to pay an installation fee of $50. The user further agree not to tamper with any of the utility owned equipment, to maintain the panel area free of shade, to pay the monthly fee and to use the system in accordance with published guidelines. This includes the requirement for the user not to attach any appliances to the system without prior approval of the utility. In return, the utility would keep the electricity supply in satisfactory conditions, replacing all failed parts, with the exception of the lights, at no added cost to the user.

► To establish a monthly fee based on the cost of operation and maintenance. This is calculated as the sum of the costs of battery replacement after an estimated life span of 4-5 years (according to the type of battery and its service requirements), the cost of replacing the controller at the end of its useful life and the utility operating cost. The monthly fee range from US$ 7 for basic lighting to over US$ 40 per month for a full system with capacity to operate a refrigerator and video as well as lights.

► The field technician who lives in or near the district to visit each installation once a month and at any other time as and when required to check the equipment and to collect the monthly fee.

► A Senior Technician from headquarters in Tarawa office to visit each district twice a year and audit the field technician's performance. Additionally, a senior technician would be available on call to assist field technicians in troubleshooting and repairs, which are beyond the level of the field technician's capability.

► To establish a user's committee within each district consisting of five to seven members. The committee would be the bridge between the utility and the users related to complaints and requests from users to the utility management, and to communicate utility matters to the users. The committee would also arbitrate in the case of proposed disconnection on the failure of the user within the district to pay the monthly fee.

The recommendations were accepted and SEC agreed that future solar lighting projects were to be designed and implemented according to the recommendations.

<u>The Pilot Project Funded by Government of Japan:</u>

In 1988 JICA committed itself to fund the electrification of the island council station on Nonouti using solar PV systems. JICA was looking at a centralised solar PV system to implement on this island. After two to three years the project was finally approved with the site changed from Nonouti to North Tarawa. The delay in approving the project provided the time to study the existing system to influence the change on the design of the project from a centralised system to a stand-alone system using the utility concept.

The project involves the provision of 55 solar systems for homes and 1 for the maneaba (community hall). North Tarawa was chosen as the site of the project because of its close proximity to South Tarawa where SEC headquarters and EPU are located making the monitoring easier to carry out. The project was completed in 1992 and monitored directly by

JICA for one year. The results were very favourable since surveys showed that the majority of the customers were satisfied with the systems. The collection of the monthly fees was prompt and the maintenance work was carried out on time and also as and when required. At the end of the project period in 1994, both JICA and the EPU reported that the solar utility concept was working well and that the concept was ready for larger scale implementation.

Expansion of the Program Funded by the European Union:

With the success of the JICA rural electrification project using the utility concept, the Government of Kiribati approved the expansion of the program to remaining islands in the Gilbert group using the European Union (EU) funding assistance under Lome II PV Follow Up program. The EU funded project involved the provision of 250 solar home systems. In distributing the 250 systems, 100 units were added to the JICA project on North Tarawa, in an attempt to fill at least part of the added demand generated by the JICA project. The remaining 150 systems were equally divided between Marakei, in the northern Gilbert group, and Nonouti in the southern Gilbert group.

The EU systems were installed in 1994 and follow up inspections by the EU were made in 1995. The follow-up inspections concurred with the results of the JICA project in that:

(a) installations were all functioning well;

(b) customer satisfaction was high; and

(c) technical maintenance was being properly carried out.

**Rural Solar Electrification Impacts on the Rural People**

It is now more than five years after the commissioning of the projects funded by JICA and the EU and the systems are still working. Of the 55 systems installed by JICA in 1992, only 5 batteries have failed. In the case of the EU project installed in 1994, only one battery had been replaced. Light bulbs and light fixtures were the main items, which have failed, but the necessary spare parts are kept in stock to provide instant replacement when needed. These items have to be ordered from abroad. The controllers were manufactured locally by the SEC using the design developed by S.P.I.R.E. since it has proven to be reliable. The success of JICA and EU projects have changed the public perception towards PV systems and this was proved by the sales of solar products to private individuals which have increased since then.

As a result of the project, the rural population has come to realise the conveniences and the benefits they can get from using a solar PV system at an affordable price. According to a survey which was carried out a few years ago, it was the women who benefited a lot from this program as they can now do extra works in the night such as weaving, sewing, family gathering and even the cooking at night. In addition school children can do their study and/or homework at night and much more. In the past the women had to make sure they finished their work before dark and unfinished housework was left to the next day, but now they can leave certain tasks to be done at night. Guttering of fish is no longer a problem for a housewife at night when the husband comes back from fishing in the evening. The social life has also been improved as the light has enabled church groups and private individuals to get together for meetings and other social gatherings at night. In the past it was very difficult to convene a meeting at night-time because of lighting problem but with solar lights in place, this is no longer a problem.

Witnessing the benefits the existing users are enjoying from having the PV solar light system, those who do not have the system have indicated their willingness to join the program. Islands not yet covered in the program have aired their need for a PV solar lighting system.

Apart from the support to social activities in villages, the PV system are not cost effective to address the energy demand of economic activities that are adaptable to the villages to support the island's economy. In most economic activities currently undertaken in the rural area such as the Fish Ice Plants to support local fishermen to market their catch, and Small Scale Cottage Industries like the Soap Factory, fossil fuel generators are more cost effective than solar in its present design capability.

**Support to the Rural Electrification Program**

In spite of the high demand of the solar-based system from the rural area, the program has been unable to provide more systems from the fees collected. This is due to the fact that the revenue obtained from the existing systems is only sufficient to cover the operational and replacement costs. For the SEC to self finance this expansion, it will need to raise its monthly fee. Any inclination to raise the monthly fee would be financially expensive to the rural household. SEC to self-finance the expansion of the solar PV systems on the rural areas will be at a snail pace. Given the limited financial options to support further expansions to the rural area the Government supports the SEC expansion activity through souring external donors to fund further expansion of the existing system at a larger scale.

In 1999 the Government, as the only shareholder of the company, approved the change in the company's name to Rural Electrification Utility Company. This is to reflect the company's objective of electrifying the rural area using not only solar energy but other sources of energy as well which are proven to be cost effective. In this connection, the company prior to electrifying the rural area will need to identify the most cost-effective technology to implement.

**The Lessons Learnt**

From what Kiribati has learned through the implementation of the solar PV powered rural electrification project, the following factors need to be considered in order for the utility concept to be successful:

a) The number of households must be carefully determined such that viability of the project is maintained. In the Kiribati case, the number of system should not be less than 50.

b) A back up service should be provided so that the systems are properly maintained. Therefore a site technician should be recruited to reduce the cost of maintaining the systems. In the Kiribati case, a single field technician could properly maintain up to 125 systems.

c) The level of income of the households in the targeted area must be determined to ensure that they can afford the fee to be imposed. In the Kiribati case, a fee of $15 a month is affordable by the majority of population in the rural area.

d) The connection of additional appliances like refrigerators and video set, apart from lights and radios, must be carefully evaluated such that the resultant fee is still affordable by the user.

e) The minimum number of systems that will allow the maintenance and operation of the program to go ahead without any financial difficulty must be targeted within a short period of time. The preferred timing will be prior to the replacement of major components such as a battery. In Kiribati case, at least 1000 systems are targeted as this is the number that will allow SEC to maintain the systems without financial support from Government.

f) As with any other project, the capability of the staff who is to maintain the system is very important and therefore training is the most important element. In Kiribati case, site technicians have been trained from time to time. In 1999 the training of technicians was carried out on Abemama, one of the outer island, where they installed a lighting system for the maneaba (community halls) in all villages on this island.

**Conclusion & Recommendations**

From the electrification programs which have been carried out by the Solar Energy Company, it can be concluded that to electrify the rural area of Kiribati, where income generating activities are limited and energy demand is low the PV solar system using the utility concept is the best approach. A monthly fee of $15, is at this time, affordable for the majority of the rural population. However, only those who can afford a fee of more than $15 a month must be allowed the connection of additional appliances. To address the energy demand of higher economic activities in the rural area the PV system in its present design stage from Kiribati experience is not cost effective and alternative source is required to promote the activity.

In addition the PV solar system program will continue to rely on external funding assistance for its expansion until at least 1500 systems have been installed. The purchasing of additional appliances to be connected must be the responsibility of the user, however, it is important that additional appliances are limited to a level that will yield a fee of not more than the level affordable by the user, in the rural area.

The sustainability approach to rural electrification through solar energy based on the utility concept to address social and minimal economic activities could prove a positive model for other countries and with minor modifications to fit local conditions and culture for the system to work.

### Overview of Renewable Energy Potential on Kiribati

Renewable Energy Resource Potential on Kiribati:

| Source | Potential |
|---|---|
| Solar | Excellent resource |
| Wind | Unlikely to be an exploitable resource |
| Biomass | Some resource |
| Hydro | None |
| Geothermal | None |
| OTEC | Good resource |
| Wave | Definite potential but extent unknown |

Source: Ellis & Fifita, 1999

Kiribati has no river, so hydropower system at any scale is not possible. Wind energy in the Gilbert group is not practical due to low and non-persistent wind speed; however, there is a possibility that Kiritimati may have a wind potential. In this connection, a wind monitoring system to determine the viability of wind speed on the island will be installed. Wave, tidal and ocean thermal energy conversions are other sources but at this point in time, the technologies are not yet commercially used. Biomass in the form of coconut residues and hardwood has been considered potential energy sources for the rural area in terms of cooking only. However, biomass use for power generation is not encouraging as the supply is insufficient and its environmental effect would be disastrous to the islands. Solar energy is an abundant source of energy readily available in Kiribati.

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### References

DG Development, 1999

Ellis & Fifita, 1999

Gillett & Wilkins, 1999

Ngalu, 1999

Pacific Islands Report, 1999

# Thursday Island (Australia)

## General Information

**Population:** 4,000

**Area (km$^2$):** 4

Thursday Island is located in the Torres Strait, which separates the most north-eastern point of Australia, Cape York Peninsula, from Papua New Guinea.

## Electricity Capacity

Installed Electricity Capacity by Source in 1997:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 6,400kW | 93.4% |
| Wind | 450kW | 6.6% |

Source: www.fnqeb.com.au/environment/renewables/ti_project.html [1]

In 1999 the Thursday Island system's maximum and minimum demands were 3.3MW and 1.3MW. These demands have increased from the time of construction of the wind turbines in 1997 when a maximum demand of 2.6MW and a minimum demand of 1MW were being experienced.

## Electricity Production

Electricity Production by Source from 1997-1999:[2]

| Source | Percentage of Total Production |
|---|---|
| Diesel | 92% |
| Wind | 8% |

Source: Morrow, 1999

## Cost of Electricity

The diesel generators at Thursday currently consume over 5 million litres of diesel annually. This equates to around AU$3.5 million with diesel around 70 cents/litre delivered to the site. The costs of electricity production at Thursday Island is approximately 30c/kWh with fuel representing approximately 75% of this cost.

## Thursday Island Wind Project

A 2 x 225 kW wind farm in association with the diesel generating plant was commissioned in August 1997.

The wind generators were established with the aim of reducing the use of diesel fuel and cutting back the emission of greenhouse gases.

Wind Regime:

From the wind data measured on Far North Queensland Electricity Corporation's (FNQEB)[3] ridge from 1989 to 1995, the annual average wind speed on Thursday Island, at 30m above ground, is around 7.5 m/s.

There is definite "windy season" between April and October when the Trade Winds blow from mainly SSE direction. Average monthly wind speeds during these months range from 6.8 to 10.6 m/s. Maximum wind gusts of 16.8 m/s were measured during these months.

During the summer months, winds are much lower and blow from all directions between E and WNW. Average wind speeds from November though March are from 2 to 5 m/s. maximum wind gusts of 16 m/s have also been measured during this period.

Environment Impact Assessment:

An Environmental Impact Assessment (EIA) was carried out, reporting on the impact of the wind turbines on the local flora and fauna, archaeological artefacts and the island community. The results of these studies were used to scope the project. Avian issues were highlighted including flight paths of migratory birds and a resident barking owl. These were considered in the positioning of the turbines.

Main Barriers for the Project:

The main obstacle for the wind project was community acceptance. Noise and aesthetics dominated issues raised during the public consulting state of the project.

Technology:

The wind turbine generators are Vestas V29-225kW machines connected to the power station bus via a dedicated feeder.

[1] This homepage is not operational anymore – please visit www.ergon.com.au instead

[2] From August 1997 to June 1999

[3] Now ERGON Energy

The turbine blades are made of fibreglass reinforced polyester, and are fixed on tubular steel towers at a height of 30 metres. The blades have a rotor diameter of 29 metres, and rotate up to 40.5 rpm maximum. The turbines start up in wind of 3.5 m/s and cut out at wind speeds of 25 m/s. Optimum performance is achieved with wind speeds of 14 m/s.

The turbines are positioned on Milman Hill, roughly one kilometre from the power station. Wind generation is at 690V, which is then stepped up to the grid voltage at 6.6kV through a padmount transformer on the site. The turbines operate in parallel with the existing generating plant with the station automatics set so that all wind energy is used.

Vestas' Graphic Control System (VGCS) is used to control the turbines and interface them to the power station automatics. This system has the ability to limit the level of wind energy penetration into the system, if required, by varying the turbine blade pitch. This minimises or eliminates undesirable impacts of fluctuating wind energy on electricity supply and the other generating plant. The "conventional" rule of thumb suggests that the maximum penetration into island systems without energy storage should be 30%. Experiences in other places suggest that this figure can safely be higher in some systems.

Organisation:

The AU$2.5 million project was financed by FNQEB, which is a State Government owned corporation.

The turbines are owned by FNQEB.

FNQEB local staff operates and maintains the wind turbines.

Production:

During the first 12 months of operation, the wind generators produced over 1.68GWh of energy. This compares favourably to the 1.44GWh predicted at the time of construction and is principally due to the better than expected wind resources for this period. Having experienced a 15.5% energy growth rate on Thursday Island for the same 12 months, this energy production equates to only 9.2% of the island's energy needs; less than the 10% predicted. The capacity factor at the end of the first 12 months was 42.5%. Savings in diesel fuel have been calculated at over 428,000 litres (or around AU$300,000) – this equates a reduction of almost 1,200 tonnes in $CO_2$ emissions. Availability of the two turbines over the first year of operation averaged 99.3% During 22 months of operation, production has totalled 2.82GWh. Energy growth on the island has been equivalent to an annual increase of 14.2%. Wind energy has accounted for 8% of total production to June 1999 and the total diesel savings are calculated of 688,000 litres.

Maintenance Issues:

A number of maintenance issues have been experienced during the first year of operation:

► continuous outages in April 1998 caused by high gear temperatures on one of the turbines were remedied with a change in the temperature parameter settings

► small rust spots have been identified mainly on the south-east side of the tower. The rust spots are being analysed to determine the full effect on the life of the tower. The atmosphere on Thursday Island is highly corrosive with salt and sand laden winds in addition to high humidity

Lessons Learned:

► timely public information is essential to obtain and keep support of residents

► micro-siting should be a process separate to the installation contract being completed before the contract specification is completed

► medium to large scale wind penetration is financially viable where diesel generating costs are high

Future Plans:

Thursday Island has FNQEB's (now ERGON Energy) prime focus for alternative sources of energy. The island's limited geographical area has a large impact on the viability of many renewable energy sources. More wind is possible with maybe two more land sites before looking to offshore applications. Ocean currents in the area have been studied and if any development in this area become commercially available, this is also a viable option.

### Contact Information


| | |
|---|---|
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### References


Far North Queensland Electricity Corporation (FNQEB) old homepage (www.fnqeb.com.au)

Information provided by Far North Queensland Electricity Corporation (FNQEB)

Morrow, 1999

# Rarutu Island (French Polynesia, France)

## General Information

**Population:** 2,000

**Area (km$^2$):** 24.3

Rurutu Island is located approximately 572 km south of the main island of Tahiti, French Polynesia. French Polynesia is an overseas territory of France and located in the South Pacific Ocean, about 3,000 km south of Hawaii and halfway between New Zealand to the west and South America to the east.

## Electricity Capacity

Installed Electricity Capacity by Source in 1999:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 1,000kW | 92.6% |
| Wind | 80kW | 7.4% |

Source: VERGNET S.A, 2000

Load from 250 kW average to 400 kW peak.

## Wind Farm

A wind farm of 2 x 40 kW wind turbines was commissioned in September 1999.

Studies started in 1995 (WASP) and wind monitoring in 1996-97 – average wind speed is 7.5 m/s on the site.

VERGNET supplied a turnkey wind farm connected on the diesel grid with distance operating - the site is approximately 4 km from the diesel plant.

Main issue is that there is no crane on the island so the VERGNET's "self-erecting" turbines were utilised.

Production:

The annual wind output is guaranteed by VERGNET for five years at a minimum of 220,000 kWh/year, which are approximately 20% of the consumption.

Organisation:

The ownership is private - Electricite de Tahiti

The operation and maintenance is locally by Electra. Electra is owned by Electricite de Tahiti.

Future Wind Projects in French Polynesia:

Studies have been carried out by VERGNET to install a 3 x 60 kW wind farm for the same operator in Tubuai Island approximately 180 km from Rurutu Island.

## Contact Information

| | |
|---|---|
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## References

Information provided by VERGNET S.A.

# Samoa

## General Information

**Population:** 235,302 (2000 estimate)

**Area (km$^2$):** 2,831

Samoa is located about 2,900 km northeast of New Zealand.

Samoa is made up of nine islands with a total land area of 2,831 km$^2$. The two largest islands, Savai'i (1,709 km$^2$) and Upolu (1,114 km$^2$), comprise more than 99 percent of the land. About two-thirds of the people live on Upolu.

## Electricity Capacity

Installed Electricity Capacity on Upolu Island in 1997 by Source:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 8.5MW | 42.7% |
| Hydro | 11.4MW | 57.3% |

Source: Cheatham, 1997

On Savai'i Island the installed capacity is 2.7 MW in two diesel stations.

## Electricity Production

Electricity Production by Source on Samoa in 1997:

| Source | Electricity Production | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 0.040 billion kWh | 61.5% |
| Hydropower | 0.025 billion kWh | 38.5% |

Source: http://www.eia.doe.gov/emeu/world/country/cntry_WS.html

## Hydropower on Upolu Island

The electricity supply on Upolu Island is hydro and diesel. There are 5 run-of-river hydro stations (7.4MW) and the Afulifo hydro station (4MW).

<u>The Afulifo Hydro Project:</u>

The Afulifo hydropower project was commissioned in 1993, one of the largest projects in the Pacific undertaken by a small utility.

The approximately US$22 million scheme included the construction of a 10 million cubic metre reservoir, a penstock, a 4MW powerhouse, and the installation of mechanical equipment and transmission lines.

Afulilo is primarily intended to reinforce hydro generation during the dry season, where there is insufficient river to operate the run-of-river hydro stations at anywhere near their wet season generation capacity. The use of Afulilo storage has saved the Electric Power Corporation a great deal in operating expenses by replacing a substantial amount of diesel generation.

The proportion from hydro varying widely depending on the recent rainfall as little storage is available. In the dry periods this can drop as low as 30% while reaching 90% average during wet seasons.

The project was financed jointly by the Asian Development Bank, the World Bank, the European Investment Bank, the European Development Fund, the Government of Samoa and Australian Aid.

<u>Grid:</u>

A 33kV and 22kV primary net on Upolu interconnects the Afulifo hydropower station, the run-of-river stations and the diesel station to main Apia distribution grid. Secondary distribution grid is provided via 6.5kV lines.

<u>Future Developments:</u>

The major future hydro development project on Upolu is an expansion of the Afulifo Scheme by a further 2 MW. Beyond this, relatively small projects only remain to be undertaken.

## Future Hydro on Savai'i Island

On Savai'i, all generation is presently all diesel apart from minor self-generation (biomass) at the Asau Sawmill. However there is a proposal for a 4 MW hydro station on the Sili River which would be sufficient to supply 100% of consumption. This was at the feasibility study stage in 1999. Japan funded the feasibility study and very likely to assist with construction.

The major potential for further hydro development is on Savai'i in the Sili Scheme which could be developed to more than twice the presently planned capacity, and the power brought to Upolu Island by an undersea cable. However, the landowners are unlikely to agree on this.

Grid:

The distribution systems at Savai'i Island are 22kV and 6.6kV. Delivery voltage to all consumers is at 415/240V.

### Other Renewable Energy Sources

PV:

The potential for PV systems is restricted since good electrification distribution systems are now extensive in both the two major islands. The areas without access to power are now restricted to two small islands plus some inland areas in each of the major islands. Even these areas have been further reduced by progressive extension of distribution systems and may be further limited by a project to link the larger of the two smaller islands to Upolu be an undersea cable. There was a PV project some years ago targeting the two smaller islands. However, this project was cancelled, possibly when the Electric Power Corporation decided it was interested in the undersea cable project.

Biomass:

Biomass has been used in the past for electricity generation at the steam power plant at the Asau Sawmill in Savai'i. While the plant is still operational, the mill has now been privatised and does not appear to be exporting significant electricity to the grid. A number of years ago a proposal for a wood-fired power station on Upolu was abandoned and this concept is no longer regarded as viable.

Solid Waste:

Some time ago there was a proposal to burn solid waste for energy. However, the volumes of solid waste were found to be insufficient. It was proposed that coal be brought in from Indonesia to supplement the waste. However, this was not accepted by the Samoan government.

### Overview of Renewable Energy Potential on Samoa

Renewable Energy Resource Potential on Samoa:

| Source | Potential |
|---|---|
| Solar | Good resource |
| Wind | Good resource |
| Biomass | Good resource |
| Hydro | Good resource |
| Geothermal | Good resource |

Source: Ellis & Fifita, 1999

### Policy

At present Samoa does not have any comprehensive policy in place although progress towards comprehensive policy was developed with SOPAC assistance.

### Contact Information

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### References

Cheatham, 1997

Ellis & Fifita, 1999

Homepage of US Energy Information Administration (www.eia.doe.gov)

Nation, 1997

Van de Velde, 1996

# Barbados

### General Information

**Population:** 259,248 (2000 estimate)

**Area (km$^2$):** 432

Barbados is the most easterly of the Caribbean Islands. It lies 435km Northeast of Venezuela and 402km to the Northeast of Trinidad and Tobago.

### Introduction

The Barbados Government has over the years been committed to developing a sustainable economy. The country relies on imported fuel for almost all of its energy production. The sustainability of the economy has been enhanced by the production of crude oil locally, use of renewable energy sources and energy conservation techniques. All projects in this area are aimed at enabling Barbados to become more independent and self reliant in catering for its energy needs.

### Renewable Energy Utilisation and Potential

Solar Energy:

Barbados has continued to actively develop solar technologies, the Government of Barbados realises that these technologies will play a vital role in developing a sustainable energy sector.

The solar water heating industry is comfortably the largest solar industry in Barbados. It has significantly grown since this technology entered the mainstream in 1974. The industry benefited under the Fiscal Incentive Act of 1974, which allowed the solar water heating businesses to benefit from import preferences and tax holidays.

In addition, the placing of a 30% consumption tax on electric water heaters helped to make these systems competitive.

There are at present three solar water heating companies in Barbados, Aqua Sol, Solar Dynamics and Sun Power. There was in 1999 approximately 31,000 solar water heaters installed on the island. This represents more than one third of households in Barbados. The water heaters have allowed Barbadians to save a combined total of more than $3.0 million per year. As a further incentive to customers, the Government allowed all solar water heaters installed costs to be deductible from personal income tax.

Recent advances in the technology have produced larger tanks of capacities of up to 8,000 gallons, which are widely used in the hotel sector. Other advances have led to greater durability and longevity of tanks as well as more resistance to calcification.

Solar Dynamics have already started to penetrate into the Caribbean market.

Barbados has also been involved in promoting solar energy for many other purposes. Other major applications include solar drying, solar distillation and solar photovoltaic production of electricity.

Solar drying techniques have been used in Barbados since 1969. The dryers are used for removing moisture from a variety of agricultural crops. In 1976 the first large-scale dryer was produced. This dryer, who has a 1600-kg capacity, was used for drying sugar cane.

Since 1990 solar drying facilities have been used to dry many different crops which include sweet potatoes, eddoes, yams and other vegetables.

The University of the West Indies (UWI), Cave Hill established a solar drying project in 1995 under the supervision of Prof. The Hon. Oliver Headley and Mr. William Hinds. They have recently developed the Artisanal Dryer, which has been exported in the Caribbean region.

The Government of Barbados has also recently been involved, along with the UWI, in the use of solar energy for the distillation of water. At present distilled water used in the science laboratories at U.W.I., Cave Hill is obtained from solar stills. The Government has entered into a joint project with U.W.I. to construct twelve solar stills to be used in secondary schools.

Within the last three years the Government of Barbados has been in the process of pursuing the development of other solar photovoltaic technology. The U.W.I. and Barbados Light & Power Company have been instrumental in providing technical assistance.

There are a number of pilot projects, which are now being undertaken. The U.W.I. has used photovoltaic panels to power a solar ice-making machine. This is a 2kW stand-alone system. It is expected that this technology will be produced commercially for fishermen who have a large need for ice in order to preserve fish.

The Government has also been involved with the programme to provide photovoltaics for the lighting of Harrison Cave, which is one of the premier tourist attractions of Barbados. The 17.8 kW system will be tied to the utility grid. A similar type of the system is also being developed by the Barbados Light & Power Company.

Schools' Solar Photovoltaic Project

The Government of Barbados recognises that solar photovoltaics will become a significant provider of electrical energy. The Ministry intends to focus on this technology in the 1999-2000 academic year. Already the groundwork has been prepared for this. The U.W.I. will be instrumental in making sure that these programmes come to fruition. The Ministry of Education has also been involved in this programme and recognises its benefits.

The main project, which has been proposed for international funding, is the Edutech 2000 Photovoltaic Project. This project which will cost approximately $450,000 US will lead to the assembly of a solar photovoltaic system which will be grid connected.

The system will be used to provide electricity for the entire school.

Funding has not been readily forthcoming for this project. The Division has decided to implement small projects of a demonstration type. A 2 kW system will be installed at a secondary school in the next academic year.

Wind Energy:

During the 1980's a number of studies were undertaken to determine the wind resources in various sections of the island. It was determined that the north and south-eastern sections of the island were best suited to development in the areas of wind. A wind turbine was constructed in 1986 with a capacity of 250 kW in the parish of St. Lucy which is to the north of the island.

However, faulty technical design and insufficient maintenance, led to the abandonment of the project in 1990.

In 1998 the British company Renewable Energy Systems Ltd. in conjunction with the Government of Barbados commenced a wind farm feasibility study. Continuous wind energy data has been collected at a site in St. Lucy and the results so far seem to suggest that wind farm development is viable.

If the project proceeds, a 6-MW wind farm will be constructed on the site and the energy produce will be fed to the utility grid.

An agreement between the developers and Barbados Light & Power (utility company) will have to be reached on the terms of the purchase of power.

Other Technologies:

There have been many technologies in renewable energy, which have also been investigated and/or implemented in Barbados. At the moment the renewable energy source that produces the largest fraction of total energy is bagasse which is used in the sugar can industry. All of the energy used in the factories is provided from this source.
Any excess is sold to the Barbados Light and Power at the avoided fuel cost.

In addition small projects using biogas from dairy farms have been undertaken.

The University of the West Indies is currently investigating Ocean Thermal Energy Conversion (OTEC). The technology will use the temperature difference between the bottom of the ocean and that at its surface to provide the energy to power a generator. It is a technology, which has much scope for islands, which are volcanic in their geology. This technology is still to be demonstrated on a large scale.

Tidal energy is also a renewable source, which has been investigated with a view to development.

**Solar Water Heating Industry**

The Solar Water Heating Industry started in 1974.The high cost of electricity, foresight of entrepreneurs, the high availability of Solar Energy and fiscal incentives all played a part in fueling the solar water heating industry.

The fiscal incentives extended to fibre glass, hot water storage cylinders, solar collectors and water based adhesives.

Essential materials used in the systems, including cooper and aluminium, have been afforded a lower tariff compared to that for electric heaters and other technologies manufactured elsewhere.

In 1984 the Income Tax Amendment gave concessions to persons installing solar water heating systems. The cost of installation of a solar water heating system became deductible from income tax.

The cost of electricity in Barbados is approximately 17 US ¢ /kWh. This cost makes the alternative of an electrical water heater unattractive. The cost of using an electric heater is $150 per month. However, the most popular 66 gallon model would cost the homeowner approximately $3000 for installation. This leads to a pay back time for the solar water heaters of approximately 2 years. The lifetime of this system is presently (15 – 20 years).

The systems used in Barbados are thermosyphonic systems. Most of the systems consist of a flat plate collector and separate tank. There are however some integrated collector systems where the collector and tank are heated in a single unit. Both systems are open systems; this means that water coming from the pipes is heated directly in the collector.

In a thermosyphonic system, cold water when heated rises up the tube to the collection tank and is stored in the tank. Cold water entering the system falls to the bottom of the collector and is heated, the cycle continues.

The storage tanks are constructed from steel and insulated using polyurethane and fibre glass. The collector panels and tubes are made of copper and the collector is covered with tempered glass. The collector is also insulated with fibre glass.

The tempered glass ensures durability and maximises transmittance. The black copper tubing maximises absorbance and the fibre glass reduces heat loss in the collector.

All storage tanks are pressured to 300 pounds per square inch.

At present there are 31,000 solar water heaters in Barbados. This represents 35% of all households.

There have been many other institutions, which have incorporated solar water heaters. These include restaurants, hotels and educational institutions. Systems are modular consisting of 66 gallon, 80 gallon or 120 gallon tanks. The tanks are then linked together to provide the required capacity.

Problems encountered by customers are mainly due to incorrect sizing or calcification. Deposits of calcium in the collector tubes as well as the tank can significantly reduce the lifetime of the system.

Use of a magnesium rod and increasing the velocity of the water through the system have helped to reduce the calcification problems. The use of stainless steel tanks is also being looked at as a long term measure to combat this. More recently, distilled water has been considered as the fluid used to be heated in the collector. Tap water will then be heated by using a heat exchange. Distilled water used in the collector would eliminate calcification problems.

**Barriers to Renewable Energy**

The Governments of the Caribbean have recognized that development in the field of renewable energy is critical to the progress of the region. In 1998 Caribbean Energy Information System (C.E.I.S) in association with U.N.D.P. (G.E.F.) developed a regional renewable energy project aimed at identifying barriers to further development.

The Regional Organization has identified (a) Finance, (b) Capacity, (c) Awareness and (d) Policy, as major barriers to development. The situation in Barbados is somewhat representative of the Caribbean in this regard.

In Barbados the success of the solar water heating industry has not been readily transferred to other technologies. Difficulties in terms of accessing finance have been a significant impediment. Investors have traditionally viewed renewable energy projects as “high risk” and funding has therefore not been forthcoming. Financing agencies have continually stressed that there needs to be more demonstration of the technologies.

The Caribbean Development Bank has played a role in this regard over the years but more needs to be done. Projects in solar energy tend to be capital intensive and even though “pay back” times are attractive the inability for individuals to access start up capital has repeatedly led to projects not getting off the ground.

International Financing Agencies have also been reluctant to help continue development in Barbados’ renewable energy sector. This is a result of Barbados’ relative high G.D.P.

There has also been difficulty in attaining the technical capacity to produce the required number of systems. Even the solar heating companies have been limited by inability to source the equipment to reduce production time and increase volume. Financing in this area would be of tremendous benefit.

The general lack of awareness of the technologies has also played a major part in the lack of development of the resource. There are many ongoing programmes which are attempting to address this problem. These include a number of school programmes and a National Energy Awareness week in order to change attitudes in the young. It is hoped that in time appreciation for the scope of renewable energy projects will be realised and attitudes will change.

Conventional Energy is still generally regarded, however, to be more “viable”. The industry has suffered through publicity given to unsuccessful projects. In the previous decade some projects failed due to lack of maintenance and use of products which were unsuitable for Caribbean environmental conditions.

There is generally a lack of professionals in the area of Renewable Energy in Barbados. Much research and development is undertaken at the University of the West Indies (CERMES) with Professor Oliver Headley and Mr. William Hinds in the forefront. This has meant that often when the technologies have been established there has not been a large enough pool of local expertise to manage and maintain the projects. It is essential that professionals in diverse academic areas become aware of the potential of renewable energy.

**Policy**

The Energy Division is committed to developing local energy resources in a sustainable manner. In the 2000- 2010 national strategic plan, the Government has set a target of 40% of energy to be produce from renewable sources. The present percentage is 25%. This is mainly from bagasse used in the sugar cane industry. The millennium programme will also provide funding for a variety of solar photovoltaic projects, outlines earlier.

No legislation is currently in place for the use of renewable energy but there is Energy Efficiency Legislation, which is being developed. It is anticipated that environmental policy will be put in place, which will allow the entire renewable energy industry to flourish.

**Contact Information**

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Ince, 1999

# Curacao (The Netherlands)

### General Information

**Population:** 143,816 (1991)

**Area (km$^2$):** 444

Curaçao is part of the Netherlands Antilles and is situated in the Caribbean Sea, near Venezuela. The Netherlands Antilles is an integral part of the Netherlands.

### Electricity Capacity

Installed Capacity in 1997 by Source:

| Source | Installed Capacity | Percentage of Installed Capacity |
|---|---|---|
| Thermal Plants | 192M | 98.5% |
| Wind Power | 3MW | 1.5% |

Source: Tujeehut, 1997

### Electricity Production

Electricity Production by Source in 1999:

| Source | Percentage of Total |
|---|---|
| Thermal Plants | 98% |
| Wind Power | 2%[1] |

Source: Rettenmeier, 1999 and Wind Power for Curacao, 1999

### Tera Cora Wind Farm

A 3 MW wind farm was commissioned in July 1993. The wind farm consists of 12 x 250 kW NedWind turbines.

The plant is owned and operated by Kodela, the state utility company.

Background:

The decision to built the 3 MW wind farm followed a successful pilot project, using a 300 kW wind turbine. The turbine demonstrated that the wind conditions on the island are fairly constant – the average wind speed during the pilot project was 7-9 m/s.

Kodela gained a lot of experience – they mastered the most pertinent aspects of the new technology, and were able to operate and maintain the wind turbine at a high skill level. Kodela also acquired the knowledge to improve on the standard European wind turbine design to permit their trouble free operation in a more corrosive and turbulent environment.

Objectives:

► To demonstrate the viability of wind power for utilities in the Caribbean region, by installing the first large wind farm there.

► To gain experience of Caribbean climatic factors on wind turbines.

► To reduce dependence of imported oil in the generation of electricity.

► To introduce wind power to local decision makers and the big audience, by dissemination campaigns, in the Caribbean area.

Technology:

The 250 kW NedWind wind turbines are 3 blades with stall regulation. Diameter is 25.3 metre and hub height is 30 metre. Cut-in speed are is 5 m/s and cut-out speed is 21 m/s.

In the design and engineering phase, corrosive environment and high humidity had to be accounted for. Special measures had to be taken to prevent the corrosive sea atmosphere from damaging the generators. The turbine nacelles and cones were made airtight, all nuts and bolts were provided with protection caps, the yaw steering vane bearings were placed inside the nacelle rather than on the outside and the aerodynamic break system was replaced.

Special wind conditions, especially strong and fast fluctuations of the wind, which normally cause disconnection of the farm, were another noteworthy issue. Due to the location, far from inhabited areas, noise problems were avoided. Stability problems, due to small and weak grid, and the effects of grid fluctuations on the turbines are important topics which have been followed. The contribution of the turbines to the peak load behaviour, and capacity credit of the wind farms, were other grid connection issues that are monitored.

Extensive monitoring and follow up is being performed by NedWind and Kodela. Along with technical issues already mentioned, the annual costs of operation and maintenance are closely monitored, to verify the assumptions made, and to project the economy of future wind farms at the region.

[1] Approximation

Performance Data:

Performance Data for 1996:

| | |
|---|---|
| Average Wind Speed | 8 m/s |
| Energy Potential | 3,520 $kWh/m^2$ |
| Gross Output | 7,916,710 kWh |
| Net Output | 1,308 $kWh/m^2$ |
| Capacity Factor | 35% |
| Energy Capture | 37.2% |
| Operating Time | 86% |

Source: Tujeehut, 1997

Innovative Concepts:

Innovative concepts include:

► Diversification of the electricity production structure from 100 % diesel oil based

► The effects of corrosive, salty atmosphere and high moisture content on the turbines

► Common operation of a wind farm together with a small totally diesel based grid, with the effects on the peak loads and capacity credits of the grid

Costs and Financing:

The total investment costs was US$ 5,000,000.

It was financed among others from the European Commission and the Dutch Government.

**Playa Canoa Wind Farm**

A second wind farm will be operational in year 2000. The wind farm is located on the island's northern shore at Plya Canoa approximately 20 kilometres up-wind of the Tera Kora wind farm.

The 9 MW wind farm consists of 18 x 500 kW, 47 metre, three bladed NedWind turbines.

The plant will be built, owned and operated by NedWind in partnership with the Dutch utility Delta Nutsbedrijven while Kodela (the owner and operator of the 3 MW Tera Kora wind farm), will buy all the power produced by the wind farm.

At little under 4,000 households – or 10% of the households on the island – will be provided with wind power.

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**References**

Rettenmeier, 1999

Tujeehut, 1997

Windpower Monthly, 1998

Wind Energy Plant Tera Cora, 1998

Wind Power for Curacao, 1999

# Dominica

## General Information

**Population:** 71,183

**Area (km$^2$):** 977

Dominica is situated between the French islands of Guadeloupe to the north and Martinique in the south.

## Energy Sector

Dominica has no known reserves of crude oil and depends in totality on imports, from Trinidad and Tobago and other oil producing and/or refining countries in the Caribbean and other regions, of gasoline, kerosene, diesel oil and liquefied petroleum gas (LPG). Gasoline and diesel are primarily used in the transportation sector whereas kerosene and LPG are used in the domestic sector for cooking etc. With LPG being used in the urban centres.

The electricity company in Dominica which operates the national grid is a private monopoly owned by the Commonwealth Development Corporation (CDC). They hold the sole exclusive licence for the generation, transmission distribution and sale of electricity in the Commonwealth of Dominica.

## Electricity Consumption

Electricity Consumption by Sector in 1994:

| Sector | Consumption in kWh | Percentage of Total Consumption |
|---|---|---|
| Domestic Sector | 22,166,000 | 52.3% |
| Commercial Sector | 12,119,000 | 28.6% |
| Industrial Sector | 2,446,000 | 5.8% |
| Street Lightning | 4,913,000 | 11.6% |
| General Lightning | 699,000 | 1.7% |

Source: Vital, 1999

At the end of 1994 there were 18,812 Domestic consumers, 1,514 Commercial consumers, 52 Industrial consumers, 172 Street lighting consumers and 977 General lighting consumers connected to the national grid.

## Electricity Capacity

Installed Electricity Capacity in 1998 by Source:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 11.1 MW | 59.4% |
| Hydro Power | 7.6 MW | 40.6% |

Source: CREDP, 2000

There is a new power station under construction with 2 x 4 MW diesel generators. It will be commissioned in the middle of 2001. A further expansion of this station to 8 MW is envisaged in 2003.

## Electricity Production

Electricity Production by Source in 1998:

| Source | Generated Electricity | Percentage of Total Production |
|---|---|---|
| Thermal Plants | 75.8 GWh | 52% |
| Hydro Power | 70 GWh | 48% |

Source: CREDP, 2000

## Policy

A national energy policy does not exist, and there is also no written or otherwise articulated renewable energy policy or statement. There is also no national development plan in place of which energy planning could become a part. No national energy planning process is in place either, although it was suggested in 1991 in the Country Environmental Profile Study to establish either an Energy Unit or an Energy Policy and Development Board/Committee acting as an inter-agency co-ordinating entity for long term planning. Energy issues are handled by the Ministry of Communications, Works and Housing.

## Experience with Renewable Energy

Hydropower:

Hydropower provided approximately 48% of total electricity generation in 1998. This proportion tending to decrease in the last 5 years due to increasing diesel capacity. The load factor of the electricity plant has been 40-50% in the last five years, reflecting the considerable decreases in dry periods.

Dominica with its mountains of up to 1432 m (4700 ft) above sea level, heavy rain fall, very thick rain forest and large number of streams and rivers flowing both east and west into the Atlantic ocean and Caribbean sea respectively, possesses considerable potential for the development of run-of-the-river hydroelectric power schemes. Except for a few, the rivers are very comparable in size. They generally follow a direct path to the sea and there are limited cases of amalgamation of streams to form larger rivers with significant catchments. The Roseau river basin has in fact been partially developed and hydroelectric power is presently being generated at three power plants at Laudat, Trafalgar and Padu. All existing hydropower stations are essentially run-of-the-river schemes in conjunction with small damns/reservoirs. They are all owned and operated by the CDC.

Several studies have been commissioned in the past to identify the island's hydroelectric resources. All studies were in agreement that there are substantial hydroelectric resources on the island. A number of other basins in the southern half of the island possess hydro potential. According to one study, apart from the existing 6,500 KW of capacity established in the upper Roseau River Basin, a further 15,680 KW of hydro-electric power can be exploited from other river basins.

Geothermal Energy:

A U.N.D.P. evaluation of Dominica's Natural Resources in 1969 concluded that the chances for finding economic quantities of natural steam for power generation in Dominica are excellent; recent volcanism and the geological structure associated with the volcanoes suggest the presence of a large, shallow heat source; the chemistry of the hot springs indicates the possibility of producing steam without an associated liquid phase; it may be the cheapest source of power in the Caribbean region.

US Geological Survey's "Resource Appraisal of Dominica, 1978 concluded: Natural deposits of copper, pumice, limestone and clays may be sufficient to justify long-term industrial development; a very good potential for geothermal power exists on the island; a study of the comparative costs of development of hydroelectric power vs. Geothermal power is needed.

French "Geothermal Studies in Dominica, May 1980" one Dominican geothermal well can probably produce 5 to 10 MW. This is much stronger than in Guadeloupe where three (3) wells are needed to produce 6 MW; Dominica's Soufriere and Wotton Waven fields could produce 50 to 100 MW each; The Boiling Lake could produce much more. It is estimated that the first large reservoir is at a depth of 400 metres to 800 metres with a feeder zone at about 800m to 1400 metres below ground level. The magma temperatures at these depths has been estimated at 200 degrees C to 300 degrees C. In addition, it is believed that a deep heat source (900 degrees C) exists at a depth of 6 to 10 kilometres. A thorough geothermal measurement program, with exploratory drillings, and a 5 MW pilot plant are needed to define and prove out the resource.

In Nov 1981, an analysis of Dominica's Geothermal Energy Potential was done in which a Dominican Geothermal Program was proposed to run over the period 1982 to 2018 at a total cost of over $365 Million involving three 100 MW Electric power geothermal plants.

It is believed that when the geothermal fields are fully developed in Dominica, electric power generation of up to 300 MW would be possible.

However to date no exploratory or other work has been done in this area in Dominica and the program has not been implemented. This is primarily because of the high capital cost involved, sufficient hydro power resources, and for reasons of an inadequate market.

Biogas:

In August 1983 an agreement on Technical Cooperation was signed between the Govt. of the Federal Republic of Germany and the Caribbean Development Bank (C.D.B.) on the execution of a biogas program in the framework of the Regional Energy Action Plan (REAP). The program was aimed at a self-sustaining dissemination of the biogas technology in CDB member countries. Dominica was one of the countries to benefit under this program.

In Dominica's economy, agriculture plays a vital role and livestock rearing is common. As most of the country's livestock is reared on small farms (0.44 ha) the largest potential groups were mainly small farmers. Organic back-yard gardening is common in certain areas. The use of slurry (bio-fertilizer) therefore exists.

Two demonstration units were constructed to demonstrate the technical feasibility of the biogas technology and a one week workshop was conducted. Another 3 demonstration units were later constructed. A biogass committee was formed whose role was to provide supervision, technical assistance, monitoring and evaluation activities. A fund was also set up to provide interest-free loans to small farmers with limited financial potential to procure materials for constructing biogass units.

Up till 1988 a total of 14 biogass units were been constructed and two were under construction.

The "technology transfer" phase of the project ended in December 1988, and evidently there has been no further dissemination of the technology since. Only a couple (if any) additional units have been built to date. The interest-free fund no longer exists and the technology never propagated as intended. In fact the program never really continued and only a fraction of the original 14 units are now functional.

The reasons for the failure of the project are still unclear, but amongst the contending reasons are:

a) The sizes of farms in Dominica are generally too small for the technology to generate a significant financial benefit to the farmer and the other benefits did not seem to generate enough of an incentive

b) The small farmers generally could not afford the capital cost (albeit not too large) involved

c) The local organisations entrusted with management of the program did not do a good job.

**Other Sources of Renewable Energy:**

Other alternative energies such as wind or solar energy have never been taken into serious consideration, because of sufficient Hydro-power resources.

Solar Energy:

Due to Dominica's geographical position (about 15 degrees North Latitude) there is substantial potential for solar energy. The solar energy resources of a typical Caribbean island are considerable, the sun providing about 6 KWh of energy every day for every square meter of land area.

There is one company on the island that manufactures and sells solar water heaters. Many recently built homes now have solar water heaters install, but there is no formal or organised promotion of the technology on the island.

Wind Power:

Since Dominica is hit by the northeast "trade winds" and has high mountains for any wind power installation, there is also great potential for this energy source. There are wind speeds of over nine meters per second. However, nothing has been formally done regarding the harnessing of wind power in Dominica.

**Main Barriers**

The main barrier is the lack of energy policy. An energy policy should encourage the exploitation of the country’s renewable energy potential by the electricity sector and by private entrepreneurs. Without establishing an energy policy with attractive incentives that encourages the electricity company to use renewables, specially hydropower, increased large-scale use of renewables will be difficult.

The general lack of awareness of the country’s considerable renewable energy potential, mainly hydropower, and possibly some wind power, is a serious barrier.

**Renewable Energy Island Nation**

Dominica has signalled its intention to become totally free from its dependence upon fossil fuel imports by 2015.

**Contact Information**

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SIDSnet (www.sidsnet.org)

# Guadeloupe (France)

## General Information

**Population:** 421,600

**Area (km$^2$):** 1,709

Guadeloupe is a group of islands in the French West Indies, off the north-western coast of South America, in the eastern Caribbean Sea. Guadeloupe is an overseas department of France.

The two principal islands - separated by the Salée River, a narrow arm of the Caribbean Sea - are Basse-Terre on the west and Grande-Terre on the east. Nearby island dependencies are Marie-Galante, La Désirade, and Les Saintes; the other dependencies, Saint-Barthélemy and Saint Martin, are located about 250 km to the north-west.

## Introduction

France's island territories and especially Guadeloupe plays an important part in the renewable industry. These territories are considered an integrated part of France, but for geographical reasons they cannot be connected to the grid. The French Electricity Board (EDF) has always been keen to install renewable energy sources in these places, where they are considered to be an alternative to diesel generation. These places have proved a valuable training ground for the French renewable industry.

## Electricity Capacity

Installed Electricity Capacity in 1999 by Source:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Diesel | 407.08 MW | 84.25% |
| Biomass | 64 MW | 13.25% |
| Hydro | 7 MW | 1.45% |
| Geothermal | 4.8 MW | 0.99% |
| Wind | 0.3 MW | 0.06% |
| Renewables Total | 76.1 MW | 15.7% |

Source: Donizeau, 2000

## Electricity Production

Electricity Production in 1999 by Source:

| Source | Percentage of Total Generated Electricity |
|---|---|
| Thermal Plants | 91% |
| Biomass | 7% |
| Hydro | 1% |
| Geothermal | 1% |
| Wind | 0.3% |
| Renewables Total | 9.3% |

Source: Donizeau, 2000

## Hydro Power

Electricity from hydropower is produced by five small plants installed in the rivers of Basse -Terre. Annual rainfall over the Soufrière volcano is 10 m. Power varies from 200 to 4,400 kW. Production has reached 20GWh in 1996. Different projects actually being considered could bring about a supplementary potential of 20GWh per year up to 2002.

## Solar Heaters

Around 12,000 houses have received solar heaters. This has saved 30 GWh or 7,680 fuel tons (metric) and the production of 19,200 of $CO_2$. There is expected to be installed 1,000 solar heaters per year.

Solar water heaters have benefited from particularly competitive prices and services since the beginning of 1996. Since then, customers have been able to sign supply contracts of energy. This contract signed with Société pour le Développment de l'Energie Solaire (SDES) guaranties hot water to the customers over a period of ten years, against an initial down payment of about 15% of the total investment followed be reasonable six-months instalments.

A specialised company (D'Locho) is in charge of the maintenance of the solar water heaters and covers hurricane risk. This service is made possible because of the reliability of the equipment, the quality of the work provided by 4 local suppliers (Ets Blandin, Guadeloupe Solaire, Solaira and Solar Edwards), and registered solar water heaters fitters.

A premium of about 20% of the total investment is granted by the French State, the European Commission, La Région Guadeloupe, EDF Guadeloupe, and ADEME to help the sale through contact. The water heaters are subsidised according to their productivity. Compared to a classical installation, the premium is doubled for collective installations.

In order to encourage the development of solar energy in the tertiary sector, hospitals, schools, etc. feasibility studies for school installation benefit from 80% financing for the total cost of the study.

**PV**

Photovoltaic energy concerns mainly electricity production for houses not linked with EDF network. In 1998 the number of family installations was approximately 1,200. PV is the power source for 40 health centres in Gualdeloupe (sponsored by the THERMIE-programme under the European Commission), for lighthouses, buoys and markers, and for remote telecommunication equipment. The target for year 2000 is to reach 1,500 families.

**Biomass**

A 2 x 32 MWe bagasse plant was commissioned in 1999 near the town of Le Moule. It is of the same type as the two bagass-plants on Reunion (please see the section The Indian Ocean for a detailed description of these plants).

**Geothermal Power**

A 5 MW pilot geothermal plant was constructed and commissioned in 1986 by EDF.

Located on the Basse-Terre island, the Bouillante geothermal plant is the only high-temperature geothermal plant in France. A 340-meter well at the foot of the Soufriere volcano provides steam (20%) and 160$^o$ water (80%). In 1996, after several years of experimenting, the plant was connected to the electricity network.

An availability rate of around 90% over the first years makes this plant highly promising. A minimum of 20 MW can probably be installed at the Bouillante site, i.e. 12% of the island’s peak demand, 15% in produced energy (base operation), and exploration of a further site seems foreseeable.

**Wind Power**

The are installed wind farms on Grande-Terre (one of the two main islands) and on the dependencies Marie Galante and La Desirade.

<u>Petit Canal Wind Farm on Grande-Terre:</u>

The first wind farm installed on the main island of Guadeloupe is located at Petit Canal, a cliff top on the eastern coast of Grande Terre, facing trade winds.

40 VERGNET SA wind generators, each 60 kW rated, build up a wind farm of 2.4 MW.

Marketed yearly wind production is 6.6 GWh.

Petir Canal wind farm was commissioned at the beginning of 1999.

<u>Wind Power on La Desirade Island:</u>

The island of La Desirade is situated 10 km east of the island of Grande-Terre. The island is 70 km$^2$ and has a population of 1,610 (1990).

The first wind farm on La Desirade Island was made of 12 x 13 kW rated wind generators. It has been modified to a 500 kW rated wind farm by replacement of 13 kW by 25 kW rated power wind generators and by bringing the number of machines from 12 to 20.

The production of the wind farm is first used to feed La Desirade grid and secondly excess current is transferred to La Guadeloupe through the submarine cable.

The marketed yearly production of this new wind farm is 2 GWh. The production started on 1996. In 1998 was 100% of the electricity consumption on the island from wind power.

A second wind farm will be constructed on La Desirade island. It will be located at Plateau de La Montagne, a location in the northeast of the island.

40 VERGNET SA wind generators, each 60 kW rated, build up a wind farm of 2.4 MW. Marketed yearly wind production is 8 GWh.

Plateau de La Montagne wind farm will be commissioned at the end of 2000

<u>Wind Power on Marie Galante Island:</u>

The island of Marie Galante is situated 30 km south-east of the two main islands Grande-Terre and Basse-Terre. The island is 158 km$^2$ and has a population of 13,463.

The first wind farm installed on the island of Marie Galant is located at Petite Place, a hill top on the eastern coast of the island.

25 VERGNET SA wind generators, each 60 kW rated, build up a wind farm of 1,5 MW. Marketed yearly wind production is 4 GWh. In 1998 the wind farm provided 30% of the electricity production on the island.

Petite Place wind farm was commissioned at the beginning of 1998.

EDF GDF Guadeloupe was interested in this project because they have experienced big trouble in 1997 when the only sub marine cable connecting Marie Galante to La Guadeloupe failed.

The formerly installed diesel power plants which were supposed to be maintained as standby plants failed to face the increased demand as well as to simply run. EDF GDF Guadeloupe had to build up a crash program consisting of rented mobile diesel power plant and to pay kWh at maximum rate during repair of the sub marine cable.

From this time EDF GDF Guadeloupe is interested in scattered wind farms in remote islands connected by sub marine cables. The existence of wind farms lightens the burden for local diesel power plants when failure in sub marine connection appears.

A second wind farm is under construction on Marie Galante Island. It is located at Morne Constant, a location north of Petite Place.

25 VERGNET SA wind generators, each 60 kW rated, build up a wind farm of 1.5 MW.

Marketed yearly wind production is 4.5 GWh.

Morne Constant wind will be commissioned in year 2000.

**Energy Plans**

The regional Power Region Guadeloupe and the regional bureau of the national Ministry of Environment and Energy, Agency de l'Environment et de la Matrise de l'Energie (ADEME), have built a energy programme for 2002. At this time 25% of the consumed electricity in the Region will be extracted from renewable energy sources.

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# St. Lucia

## General Information

**Population:** 152,335 (1998 estimate)

**Area (km$^2$):** 616

St. Lucia is located in the south-eastern Caribbean Sea, between Martinique on the north and Saint Vincent on the south.

## Renewable Energy Island Nation

At a press conference in November 1999 at the Fifth Conference of the Parties (COP5) of the United Nations Framework Convention on Climate Change (UNFCCC), St. Lucia became the first nation to announce its intention to transform its energy systems to a fossil-fuel-free base to the extend possible, and become a sustainable energy demonstration country for the rest of the world.

The US based organisations Climate Institute and Counterpart International are assisting the Ministry of Finance and Planning of the Government of St. Lucia in developing the Sustainable Energy Demonstration Country Project. This is to facilitate St. Lucia becoming independent of importing fossil fuel and transform its energy base to systems based on renewable and energy efficient systems.

At the request from the St. Lucian Government, working with the Island States stakeholders and a team of international experts, the Climate Institute intends to develop a comprehensive Sustainable Energy Plan for St. Lucia. The plan shall also quantify the greenhouse gas offsets as a result of the implementation of the plan and identify ways to benefit from trading of carbon credits and utilising other international incentives that may be made available.

The project will result in an action plan with identification of project opportunities and financing schemes. The project will also identify and implement policy reforms, capacity building and awareness activities. The Sustainable Energy Plan for St. Lucia will be integrated within the National development planning process and use energy transformation measures as a tool for sustainable development. It is expected that by the end of the year 2000, considerable progress would have been made and a success story presented at the COP6 Meeting at Hague in November, 2000.

The Sustainable Energy Demonstration Country Project will demonstrate that:

► With the necessary technology and political will, nations can achieve energy self-sufficiency, leapfrogging the current fossil fuel technologies.

► Energy can be used as a tool for sustainable development and by comprehensive energy planning, nations can reap the economic and environmental benefits of green energy policies and actions.

► Dramatic reductions in fossil fuel use are possible and the small island states are taking the lead in greening their energy systems and meaningfully participating in the international efforts to bring down the GHG emissions.

The overall intention is to pursue all mature renewable energy technologies with the view of “greening” the island’s energy mix. In this regard renewable energy technologies will assist in the following:

► diversification in the national energy mix

► reduction of fuel import bills

► reduce reliance of imports

► help insulate the country from future upheavals in the world market

► promote technological advancement

► help meet Greenhouse gas emission reductions under the UNFCCC

► demonstrate national commitment to the objectives of the UNFCCC and the Kyoto Protocol

Implementation:

The planning and implementation process will have the following stages:

Step 1: Negotiation with the Government Energy Ministry, and the utility to an agreed program protocol.

Step 2: Assemble a project team, including island states stakeholders, potential investors, funders and experts.

Step 3: Start working to develop the "Sustainable Energy Plan" with the local stakeholders that would be based on current energy needs and projections, and would include the capacity building and public awareness components.

Step 4: Conduct necessary resource assessments, feasibility studies and technology assessments to identify project opportunities and facilitate transfer of appropriate technologies. Also, some projects will be fast tracked during the planning period to facilitate public understanding.

Step 5: Agree on the "Sustainable Energy Plan" and arrange financial packages to fund the various components of the Plan with the help of private sector, donors and international funding mechanisms. Establish linkages with other regional activities

Step 6: Begin to execute the plan and demonstrate project as a learning tool for other small island states and other developing countries.

**Existing Energy Situation**

Energy demand in St. Lucia, like most of the small island states in the Caribbean is met by the importation of refined petroleum products such as petroleum, diesel and kerosene. The dependence on imported energy, coupled with a disproportionately high rate of increase in energy consumption has serious implications for the island's security of energy supply and balance of payments position.

All generating capacity in St. Lucia is diesel-powered. The local utility company LUCELEC is a privately owned company with shares owned by the Government and other entities. Regulatory reforms were enacted in 1994 in which the Public Utilities Commission was abolished and a regulatory regime was established whereby LUCELEC is allowed a fixed minimum rate of return. LUCELEC currently has approximately 66 MW of installed capacity, all diesel fired to met a peak demand of about 44 MW. Currently the residential customers are getting electricity as a cost of US $0.16/KWh and commercial and industrial customers at a rate of $0.20/KWh

Over the past ten years, the utility has experienced annual growth rates in both sales and demand averaging approximately 10%. LUCELEC recently installed 30 MW of new diesel based generating capacity and with the growing demand from the Tourism Industry, it is expected that 31 MW of additional capacity will be needed over the next eight years.

St. Lucia imports about 95,000 Tons of oil equivalent (TOE), at a cost of some US$25 million or 20% of the island's total export earnings. About 30% of this is used for electricity generation. The total electricity generated in St. Lucia is about 200,000 kWh.

About 90% of households have access to electricity. There are some 40,000 residential and 5,000 commercial and industrial customers. Annual sales are about 150 GWh per year.

The Ministry of Finance and Planning is the government ministry responsible for the development of energy policy, programs and projects while the Ministry of Communications, Works and Public Utilities oversees the operations of LUCELEC

**Renewable Energy Resources and Experiences**

Solar energy:

St. Lucia is blessed with an abundant amount of sunlight. However, only a limited use of solar applications can be found. The high cost of heating water using electricity is causing an increasing number of domestic and commercial consumers to switch to solar water heating. Government has encouraged this through the removal of both duty and consumption tax on solar heating units and on components used in their manufacture. Many of these heaters are seen on newer buildings and mainly in the city of Castries and surrounding areas. It is expected that the waiver of consumption tax and import duty on all renewable technologies will further increase the use of solar and other renewable technologies.

There is a need to determine: What levels of incentives are economically justified? And what exactly are the economic benefits of solar water heating?

Although most of the population (90-95%) has access to electricity, there is a large rural area and some communities that are far from the electric grid. Solar electricity for water pumping, lighting and other uses can play a useful role in these areas.

Photovoltaic (PV) lighting systems have been installed on four storm shelters with Italian/UN Trust Fund assistance as a demonstration of renewable technologies. About 70 additional storm shelters that are either not connected to the grid or would lose electricity in the event of a storm are in need of this emergency assistance. Most of these shelters are located in schools and churches.

The greatest potential for crop drying by sunlight is for the drying of ginger and other spices such as clove, nutmeg, cinnamon, chive, thyme and peppers. Solar energy is also used for drying cocoa beans and coconuts by open exposure to the sun. There are a number of locally built solar dryers - wire baskets or cabinet dryers, but their use is on the decline. There is a need for the development of cheap and durable dryers.

Incentives are also necessary to encourage small businesses to produce dried fruit especially for the tourism market, which would create a market for these dryers.

Wind Energy:

Studies in St. Lucia suggest that areas of moderately high speed exists on the island especially on the exposed locations on the windward coat of the island, and in particular at the northern and southern extremities, where the prevailing wind flow has been diverted around the central mountain range.

The Government of Saint Lucia and the Saint Lucia Windpower JV, a joint venture company formed by Probyn Company of Toronto, Canada and York Windpower of Montreal, Canada has completed an assessment of wind potential near the Eastern Coast of the island. Based on the results of this one-year continuous wind resource assessment, the government has submitted a proposal to construct a 13.5 MW wind farm to the local utility.

The local utility LUCELEC has expressed interest in purchasing power from wind, provided that the cost of power is below existing variable costs (i.e. the fuel cost of generation), and that no investment by the utility is required.

The introduction of this renewable energy source will likely require developmental support.

Geothermal Energy:

Geothermal energy may be St. Lucia's principal renewable energy resource. Several exploration programs have been carried out during the last two decades, funded by U.S. and European companies and the United Nations. The drilling explorations have confirmed the presence of a geothermal resource capable of supplying electricity to the national grid. However, no adequate determination of feasibility is currently available.

Advantage is being taken of improvements in geothermal technology to conduct a reassessment of the potential resource, which should be completed by October 1999.

Biomass:

St. Lucia is mainly an agricultural country. There are many forms of biomass used including charcoal, firewood and agricultural products such as coconut shells. In 1996, it was estimated that 8,276 tonnes of biomass were consumed.

20% of the land in St. Lucia is uncultivated marginal land or scrublands suitable only for forests. According to a study conducted by the University of the West Indies, there is a potential to supply a fuel demand of up to 24,000 families or nearly 144,000 people. Proper management and technical assistance is needed to develop pilot schemes.

Concerns over deforestation associated with the consumption of charcoal and firewood has seen a decline in the promotion of this source of energy.

In an effort to promote the sustainable exploitation of forest covers, government has established a few "fuel farms" planted with fast growing leucaena trees, which are harvested under controlled conditions.

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# St. Vincent and the Grenadines

## General Information

**Population:** 181,188 (2000 estimate)

**Area ($km^2$):** 389

Saint Vincent and the Grenadines lies south of Saint Lucia and north of Grenada. The largest of the Grenadines include Bequia, Canouan, Mustique, Mayreau, and Union. The total area is 389 $km^2$, of which the island of Saint Vincent constitutes 344 $km^2$.

## Electricity Capacity

Installed Electricity Capacity by Source in 1998:

| Source | Installed Capacity | Percentage of Total Installed Capacity |
|---|---|---|
| Thermal Plants | 18 MW | 76.3% |
| Hydro Power | 5.6 MW | 23.7% |

Source: CREDP, 2000

## Electricity Production

Electricity Production by Source in 1997:

| Source | Percentage of Total Production |
|---|---|
| Thermal Plants | 67.2% |
| Hydro Power | 32.8% |

Source: www.eia.doe.gov/emeu/world/country/cntry_VC.html

## Hydropower

St. Vincent is an island blessed with high rainfall in the interior mountain slopes, and is a current user of hydropower. Two plants are in operation, the South River and the Cumberland River power stations. The South River turbine is to be upgraded, but there will not be any large increase in yield.

## Renewable Energy Potential

There has been interest in wind energy and PV on the Grenadines Islands for some time, though not in a systematic way.

<u>Solar Water Heaters:</u>

There is a limited use of solar water heaters. Solar water heaters are offered by major appliance dealers, but their costs make them unattractive when compared with electric shower heads. There has never been any attempt at local manufacture, no doubt because of the perception of unfavourable economics. None the less, the potential for solar water heating is good, due to the high electricity tariff. However, it is not likely to win widespread acceptance unless it is part of a national campaign to use renewable energies.

<u>PV:</u>

PV are used on boats and navigational aids, as well as use in radio repeater stations. However, even for supplying the remote islands, the use of this technology has not spread. Duty free concessions are available, but they have to be applied for on a case by case basis, making it an expensive and time consuming process to import the panels.

<u>Wind Power:</u>

Historically, the Government did show some interest in wind power, especially for the Grenadine Islands. Though the wind speeds are more than adequate, it has been difficult to get any project going, even in the Grenadines.

<u>Biomass:</u>

Apart from past use of bagasse in the now shut down sugar factory, and the use of charcoal in the interior farms and small settlements, biomass is not used in the country.

<u>Biogas:</u>

Biogas has been effectively used in St. Vincent by farmers in the high mountains to provide fuel for domestic use and for the fertiliser by-product. However, its use is not widespread.

<u>Geothermal Power:</u>

There is an active volcano on St. Vincent, and the Government has been approached by American financiers interested in exploiting this possible resource. However, the Government was unhappy about the contractual details and did not pursue the matter. It remains a distant possibility.

<u>Summary Regarding Potential:</u>

There is a low level of awareness of the potential of renewable energy. The renewable energy in greatest use is hydropower, and this has been so for such a long time that it is almost considered a conventional source. Wind power is capable of contributing to the national demand, and some additional hydropower could be developed if oil prices rise to a level which makes development of additional sources economic. Wind and solar (thermal and PV) could be useful in the Grenadines Islands if the systems are properly designed.

The Caribbean islands, and St. Vincent in particular, may lose an opportunity if they do not develop wind farms while turbines in the 5-600 kW range are still available, as the current trend is to larger machine sizes. Using more of smaller machines will result in a more uniform output of power form the wind farm(s). The use of very large machines may be unfeasible in some small islands.

### Policy

There is no specific national energy policy. In the national strategic plan, energy is not mentioned as an issue.

### Main Barriers

The main issue is the absence of a national energy policy, which might guide energy investments in St. Vincent and the Grenadines. The next issue of importance is that private power producers should be allowed to connect to the grid.

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# Appendix 1: Overview of Islands in the First Edition and not included in the Second Edition

In Table 7 below are in very summarised form presented the islands from the first edition of Renewable Energy on Small Island from April 1998 that is not included in this edition due to absence of up-to-date information.

The first edition can be downloaded in PDF-format on the homepage of Forum for Energy and Development (FED):

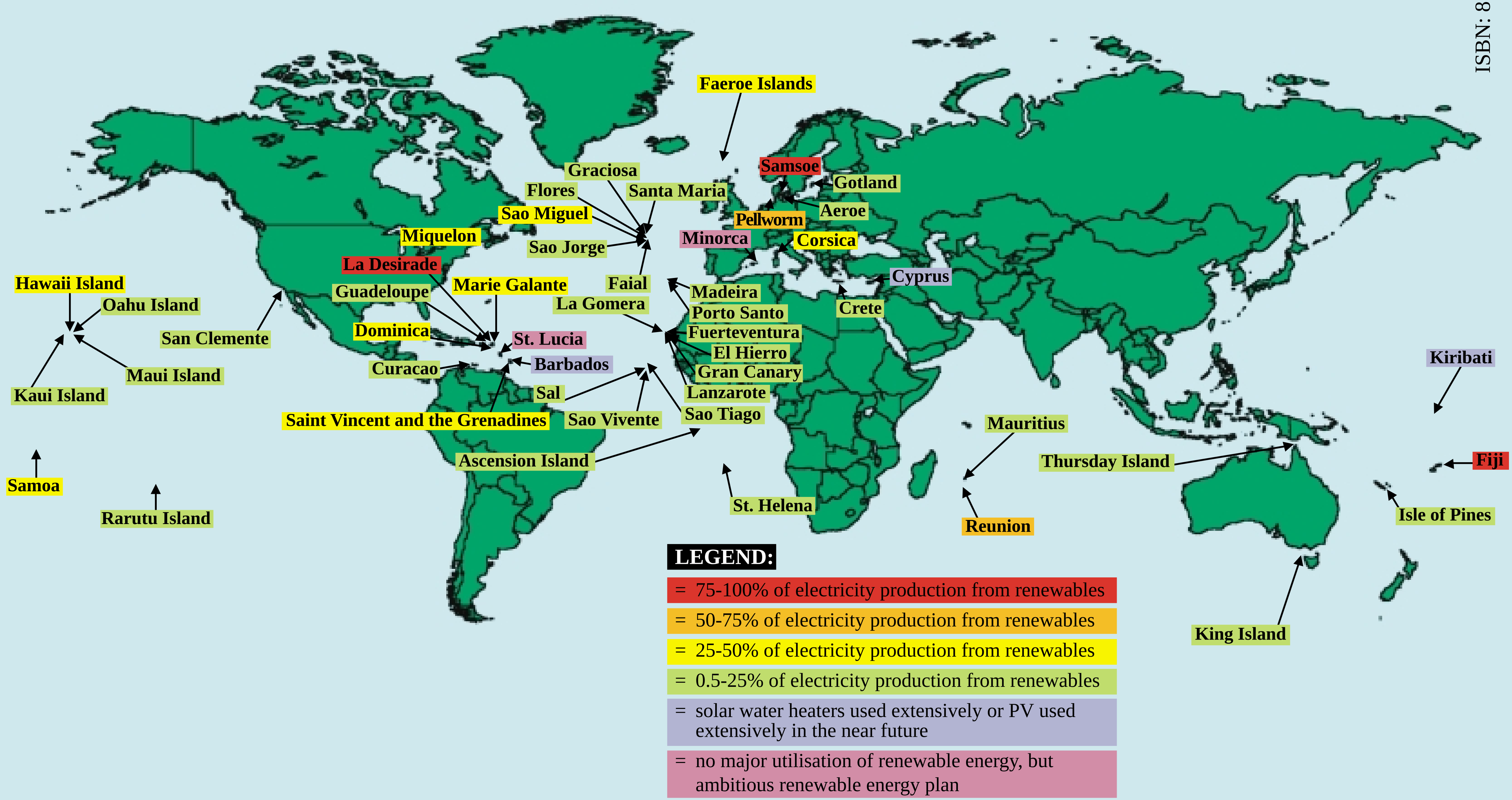
http://www.energiudvikling.dk/projects.php3

### Table 7: Islands Presented in the First Edition and not in the Second Edition[1]

| Island | Total Percentage of Electricity Production from Renewable Energy Sources | Renewable Energy Sources Utilised | Year | Island Connected to other Electricity Grid | Renewable Energy Goal/Plan/ Strategy | Area ($km^2$) | Population |
|---|---|---|---|---|---|---|---|
| **Agios Efstratios (Greece)** | | A 100 kW wind turbine | | | | 50 | 300 |
| **Bornholm (Denmark)** | 7.3% | 8.535 MW of wind turbines, 4 district heating systems using biomass, two 55kW biogas systems used to producing electricity, and a small amount of solar water heaters | 1997 | Yes | | 587 | 45,000 |
| **Bering Island (Commander Island, Russia)** | | 2 x 250 kW NEG Micon wind turbines | 1994 | No | | 1,000 | 1,000 |
| **Coconut Island (Australia)** | 5% | 25 kW PV and 10 kW wind power | 1997 | No | | 0.5 | 200 |
| **Channel Islands National Park (USA)** | | There are 60 small renewable energy installations on the five islands in the Channel Islands National Park | 1997 | | | | |
| **Fair Isle (UK)** | | One 60 kW and one 100 kW wind turbine | 1997 | | Up to 90% of the island's electricity demand from wind | 6 | 70 |
| **Fernando de Noronha (Brazil)** | | One 75 kW wind turbine | 1996 | No | Considering the installation of further two wind turbines on the island | 30 | 2,300 |
| **Foula (UK)** | 50% | One 50 kW wind turbine and one 15 kW hydropower plant | 1997 | | There is not a renewable energy plan for the island | 13 | 43 |
| **Flinders Island (Australia)** | 5.7% | 1 x 25 kW and 1 x 55 kW wind turbine | 1997 | No | | 1,350 | 950 |
| **Föhr Island (Germany)** | 4.3% | Wind power and a small utilisation of PV | 1995 | No | | 82 | 8,700 |
| **Galapagos Islands (Ecuador)** | 0% | None. | 1997 | No | 50% self-sufficiency of energy demand (excluding transport) within a few years. | 7,882 | 12,000 |
| **Hiiumaa (Estionia)** | 4% | A 150 kW wind turbine | 1997 | Yes | Yes | 1,000 | 11,800 |

[1] Blank cells means that information was not available

| Island | Total Percentage of Electricity Production from Renewable Energy Sources | Percentage of Electricity Production by Type of Renewable Energy Source | Year | Island Connected to other Electricity Grid | Renewable Energy Goal/Plan/ Strategy | Area | Population |
|---|---|---|---|---|---|---|---|
| **Islay ( UK)** | | A 75 kW wave power plant | 1997 | Yes | | 611 | 3,500 |
| **Leasoe (Denmark)** | | A district heating plant in the town of Byrum using wood chips | 1997 | Yes | Yes | 114 | 2,400 |
| **Lemnos (Greece)** | | 1.140 MW wind turbines | 1995 | No | | 475 | 14,923 |
| **Kythnos (Greece)** | | 100 kW PV and 5 x 33 kW wind turbines | 1997 | | | 100 | 1,600 |
| **Puerto Rico (USA)** | | 247 MW of hydropower and 40,000 solar water heaters | 1993 | | There exists a renewable energy plan for the island | 9,104 | 3,810,000 |
| **Rathlin Island (UK)** | 70-80% | 3 x 33 kW wind turbines | 1994 | No | | 17 | 120 |

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