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South Pacific Islands

Geothermal energy for electricity production

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Abstract

This report is a summary of geothermal energy in the South Pacific Islands, and possibilities for the IIDA to assist these small countries in utilising it. There is little need for space heating on the islands, so only geothermal areas where the potential for utilising geothermal energy for electricity production are discussed. Each island's feasibility for geothermal development is dependent on the flow of thermal water that can be harnessed, and market conditions. The islands under discussion here are located in the South Pacific, and were formed in connection with tectonic action between the Pacific Plate and the Australian-Indian Plate.

Geothermal energy is found widely in the South Pacific Islands, and therefore conceivable that other considerations will determine events when the time comes to decide which islands shall receive support. Knowledge of local geothermal systems must be developed, along with slow and careful steps to implement growth in this sector.

Key words	ISBN-number
South Pacific Islands, geothermal energy, utilisation, renewable energy, electricity production	Signature of project manager
	Reviewed by BS

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1 Introduction

The Icelandic International Development Agency (IIDA) has requested Iceland GeoSurvey (ÍSOR) to implement a brief assessment of geothermal resources in the South Pacific Islands, as well as determine the feasibility of the IIDA assisting these small countries in utilising geothermal energy. There is little need for space heating on the islands, so this study will focus on surveying the South Pacific Islands' geothermal potential with regard to utilising this resource to generate electricity. Temperatures over 250°C are well suited for electricity production in steam power plants, while lower temperatures are exploitable using binary power. The feasibility of each location depends on the amount of harnessable thermal energy, and market conditions.

The islands under discussion are in the South West Pacific and were formed in connection with tectonic action between the Pacific Plate and the Australian-Indian Plate. This upheaval gave birth to several smaller plates that have complex interplay. These convergent plates are part of the Ring of Fire, or circum-Pacific seismic belt that encircles the Pacific Ocean. About 85% of the world's wattage generated with geothermal energy is from this energy-rich area.

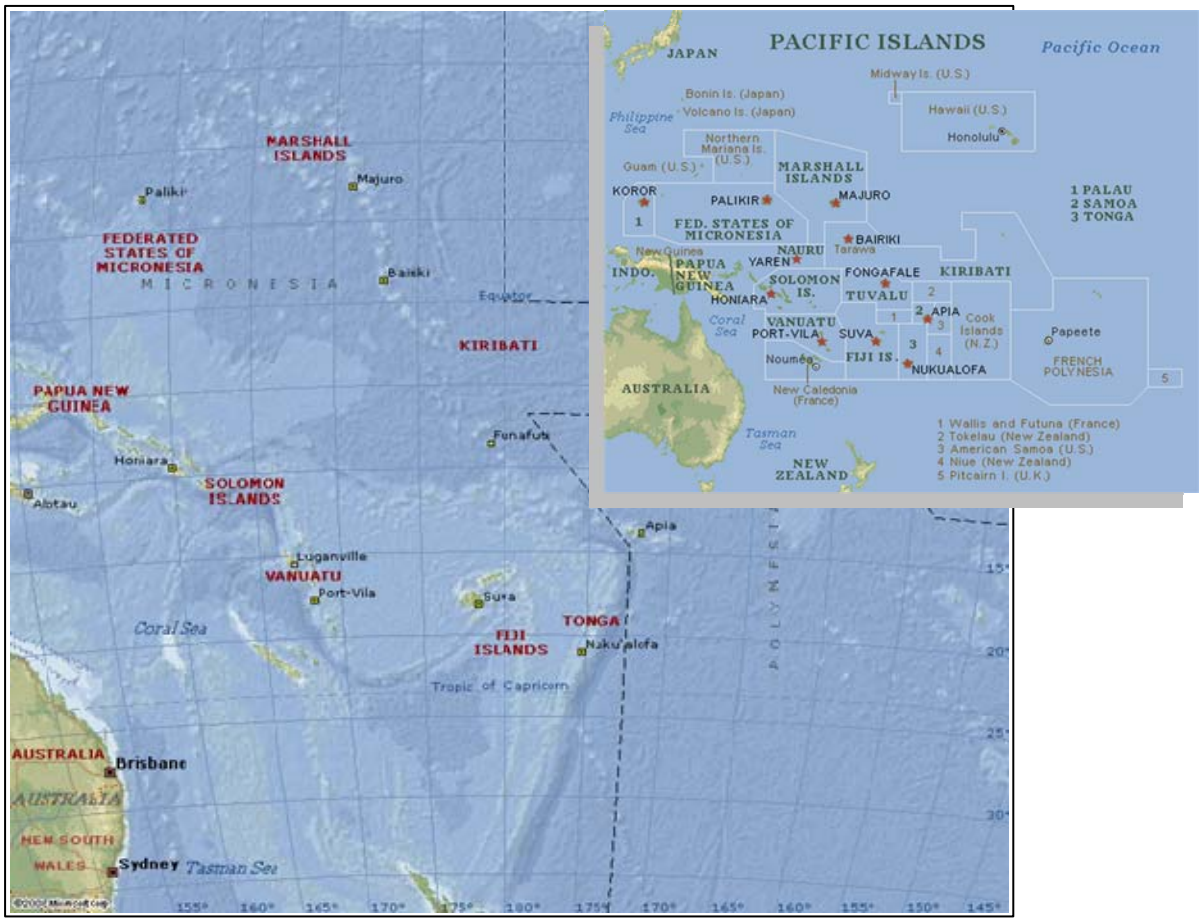


Photo 1. *Pacific Islands. The large map depicts outlines of submarine ridges on the convergent plates that interlink the islands. The inset indicates boundaries and ownership. ("Pacific Islands," Microsoft® Encarta® Online Encyclopedia 2008).*

2 Electricity production in the South Pacific Islands

If anything is to be learned from experiences that small countries have gained from geothermal energy projects, then Valgarður Stefánsson (an employee of the National Energy Authority of Iceland) pointed out in February 1987 that over the previous 35 years, several studies had been conducted regarding utilisation of geothermal energy on St. Lucia in the Caribbean. Despite the existence of significant geothermal energy, it had not been utilised. However, drilling was conducted on St. Lucia in 1987–88, and although the heat proved to be sufficient – over 240°C – water flow was not. Various surveys have since been conducted with promising results, but geothermal energy has still not been utilised on St. Lucia.

In this discussion, geothermal areas refer to places where heat in the ground and/or liquid on the surface are above the average temperature that can be expected in the respective area due to the interplay of sea and sun (climate). Even if a geothermal area is not found in a particular land or island, geothermal energy may nevertheless be present below the surface.

Before examining the geothermal areas, Table 1 has been included to provide an overview of electricity usage on the islands and installed wattage by production methods in 2005. For comparative purposes, information is included about Iceland for the same year.

Table 1. *Electricity production in the South Pacific Islands. Comparative figures for Iceland are provided in the bottom row (prior to the Kárahnjúka Power Plant and expansion of the geothermal power plants in Hellisheiði and Reykjanes). Data provided by the EIA (Energy Information Administration).*

Island name	**Total electricity production (thous. MWh) in 2005**	**Installed wattage in 2005, MW**			
		Coal, oil and gas, MW	Hydroelectric, MW	Geothermal energy, solar energy, wind energy, wood burning and waste heat, MW	Combined wattage, MW
Fiji Islands	**952**	120	80		**200**
Kiribati	**9**	3			**3**
Niue	**3**	1			**1**
Nauru	**30**	10			**10**
Papua New Guinea[1]	**3596**	300	200	36	**536**
Samoa Islands	**106**	20	12,4		**32.4**

[1] Data from the EIA did not include geothermal energy production on Lihir Island, possibly because this involves a private company and production is not connected to the distribution network. A 36-MW power plant, owned by Lihir Gold Ltd., is included in the table.

Solomon Islands	**55**	12			**12**
Tonga	**34**	8			**8**
Tuvalu					
Vanuatu	**41**	12			**12**
Iceland	**8530**	142	1163	203	**1508**

There is no further discussion on some of the islands listed here and in tables. This is because of the strong economic and development assistance that these islands accept from large economies. These include onetime Trust Territories of the USA (Marshall Islands, Palau and Micronesia), countries dependent on development and defence assistance from Australia (Nauru), in free association with New Zealand (Niue), and overseas territories of the French (New Caledonia) and British (Pitcairn Island).

The overall structure of primary energy consumption on the islands is depicted on Photo 1. Papua New Guinea is by far the largest energy consumer, and when added to Fiji these two islands account for over 90% of energy consumed by the islands covered in this study.

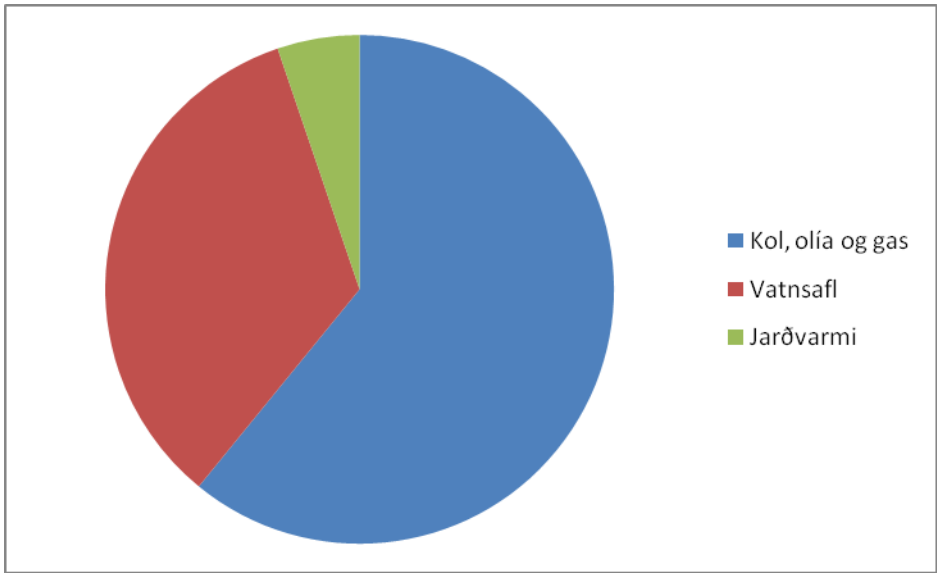


Photo 2. *The composition of overall primary energy consumption on the islands. Fiji and Papua New Guinea consume over 90% of the energy produced by the islands covered in this study. Most of it is produced using oil (rather than coal or gas), and an effort is made to use plant oil, available on the islands, blended with diesel fuel. Geothermal energy is only utilised for electricity production on Papua New Guinea.*

3 Renewable energy

3.1 Geothermal energy

In 2002, a grant was applied for from the USGIC (United States Geothermal Industries Corporation) for an exploratory project in the field of geothermal energy on the South Pacific Islands, which was named PIRGADI (Pacific Island Regional Geothermal Assessment and Development Initiative). The project was not financed at that time, but the party responsible for preparatory work, SOPAC (South Pacific Islands Applied Geoscience Commission), has now begun revising its application in response to rising oil prices and lower start-up costs for small power plants (<10 MW) due to technological advances.

The 18 member countries of SOPAC are Australia, Cook Islands, Micronesia, Fiji Islands, French Polynesia (associate member), Guam, Kiribati, Marshall Islands, Nauru, New Caledonia (associate member), New Zealand, Niue, Papua New Guinea, Samoa Islands, Solomon Islands, Tonga, Tuvalu and Vanuatu. Details concerning SOPAC and USGIC are in Appendix 1. Collaboration between SOPAC and USGIC indicates that it would be simple for the islands in question to receive strong support from the USA to develop geothermal energy. In addition, support can be expected from countries in the relative vicinity that have achieved excellent results in geothermal energy utilisation, for example Japan, Indonesia, Philippines and New Zealand.

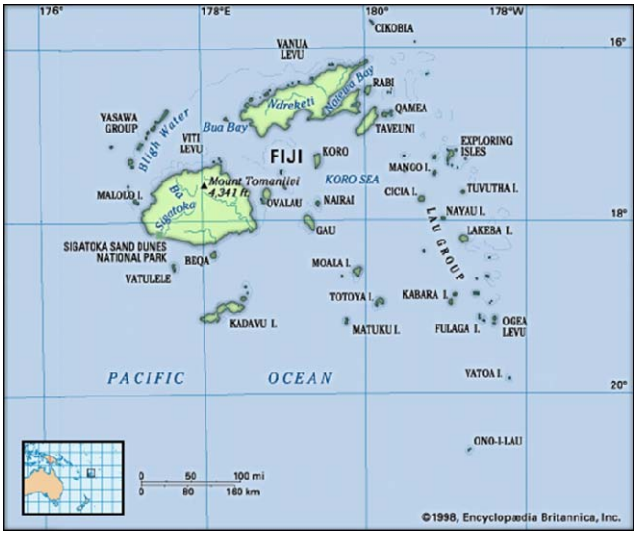
Of the 18 main and associate members of SOPAC, six main members are being further assessed for the PIRGADI initiative: Fiji, Vanuatu, Papua New Guinea, Samoa Islands and Solomon Islands.

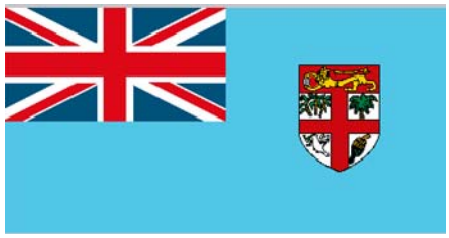
Assessments of geothermal energy for electricity production on several of the islands under discussion are shown on Table 2.

Table 2. *Wattage considered feasible to produce using geothermal energy on several of the South Pacific Islands (Olson, H.J., 1995).*

Country	MW
Fiji	50
Papua New Guinea	300
Solomon Islands	50
Tonga	50

4 Fiji Islands





Capital:
Suva
Official languages:
English, Fijian dialect
Population (estimate):
(2007) 839,000
Size:
18,272 km^2

Two primary geothermal prospect sites are on Fiji: Savusavu and Labasa, both located on Vanua Levu, the second largest island of the Fiji archipelago. There is no volcanic activity on Fiji, and the 40 thermal springs (several thermal springs are outside the primary geothermal areas) originate from extinct volcanoes that are up to five million years old (Plio-Pleistocene epoch). The majority of electricity production is generated on the most populated island, Viti Levu, mainly from hydropower (80 MW hydroelectric generating station, Wailoa), followed by electricity generated by diesel-powered plants and bagasse-fired steam cogeneration. The geothermal power station on Vanua Levu has proved important since the local sugarcane industry (FSC – Fiji Sugar Corporation) needs about 4 MW more electricity for its production than is generated by bagasse-fired steam cogeneration. Hydro-generated electricity is small on Vanua Levu, or about 2 MW. Forecasted energy needs over the coming years are estimated at 2 MW in the vicinity of Labasa, and 21 MW at Savusavu. If the two grids are joined and extended, as planned, production capacity is expected to reach 25 MW. A feasibility study on utilising thermal heat to produce ethanol from cassava meal conducted in 1981 (McNitt, report for UNDP) concluded that it was not viable.

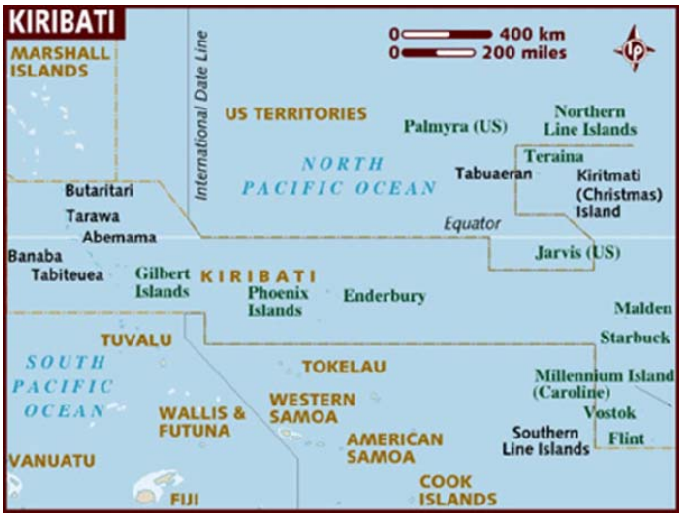
4.1 Savusavu

There are at least eight thermal springs along the Savusavu peninsula, and infrared imagery of the area suggests the possible existence of others. The hottest spring water temperatures are near boiling, but chemical analysis of the water indicate that temperatures of about 170°C are found in the geothermal system, mixed with very little seawater. Aeromagnetic surveys point to there being a trending range at depths of less than one km. It is recommended that confirmatory slim holes be drilled to a depth of at least 800 metres.

4.2 Labasa

South of Labasa, a town located in the centre of the north side of Vanua Levu, is a geothermal belt comprising eight groups of hot springs that stretch over a 19-km-long area. Geochemical studies indicate that the temperature of the thermal region is as much as 120°C. Despite the relatively low geothermometric temperatures found in Labasa, it has been recommended that three, 800-metre-deep slim holes be drilled in connection with confirmatory drilling in Savusavu.

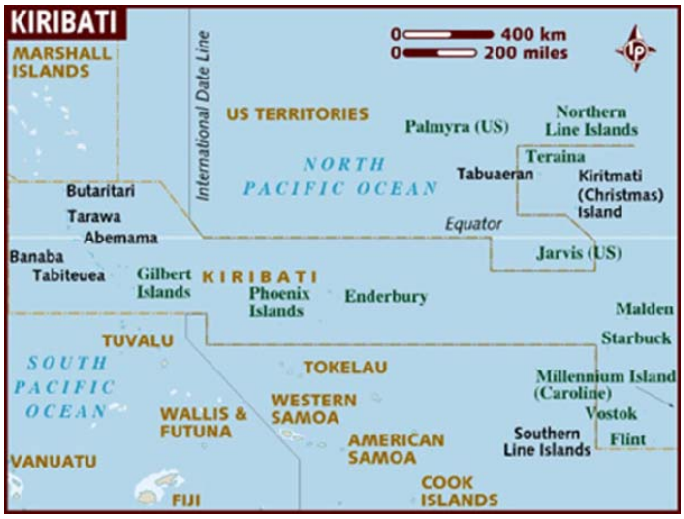
5 Kiribati



Government locations:
Village in Bairiki (executive branch), Amb (legislative branch), Betio (judicial branch) South Tarawa
Official language:
English
Population (estimate):
(2007) 95,500
Size:
811 km^2

There is no known geothermal activity on Kiribati, but the so-called OTEC method to develop energy has been considered feasible, if costs are not prohibitive. OTEC (Ocean Thermal Energy Conversion) uses the ocean's natural thermal gradient – the ocean's layers of water have different temperatures –– to generate electricity: the waters around Kiribati are rather shallow and hot, while temperatures are reasonably cold at a depth considered manageable for exploitation purposes. Other South Pacific Islands discussed here are considered promising for such energy utilisation (independent of costs), in particular the Samoa Islands, Vanuatu and Fiji.

6 Papua New Guinea



Capital:
Port Moresby
Official language:
English
Population (estimate):
(2007) 6,331,000
Size:
462,840 km^2

There is substantial geothermal activity on Papua New Guinea, which is comprised of about 600 islands. The most prospective areas for initial investigation regarding new electricity generation are considered to be on the northern coast of New Britain Island, from Willaumez Peninsula east to Gazelle Peninsula. In that region, there are at least seven geothermal sites: Bamus, Galloseulo, Walo, Kasoli-Hoskins, Garbna, Pangalu-Talasea and Bola. There are also geothermal sites on Bougainville Island and D'Entrecasteaux Islands. Electricity is already generated from thermal energy on Lihir Island. It is not connected with the main transmission lines of the islands, but directed to the gold mining operations of Lihir Gold Ltd. The mine was previously operated by Rio Tinto. There are 22 active volcanoes and 14 dormant ones on Papua New Guinea. Several known volcanoes on the islands are Manam, Karkar, Lamington, Langila, Ulawun, Rabaul and Bagana.

6.1 Lihir Island

Lihir Island is about 700 km northeast of the islands' capital, Port Moresby. Geothermometric equilibrium temperatures on the island are as much as 300°C, and are exploited through several powerful holes, some of which reach a depth of 1000 metres. Thermal water flow is rapid, and has a temperature of about 250°C when reaching the surface. Thirty-six MW are produced for the gold mining operation, and work has begun on expanding capacity to 56 MW. Gold and thermal energy operations function well together: the drilling and harnessing of thermal water lowers the water level in the area, which simplifies further mining operations.

6.2 New Britain

The Pangalu-Talasea and Kasoli-Hoskins geothermal fields are located in the middle of the north coast of New Britain, and are associated with recent volcanic activity. The

geothermal areas comprise numerous hot springs, fumaroles and mud pools with temperatures that range from 90-101°C. Hydrogen sulphide (H_2S) and carbon dioxide (CO_2) are at above-average levels. Silica and chloride content suggest that geothermometric equilibrium temperatures could be about 300°C

The fluids in the geothermal areas to the east of the Willaumez Peninsula have an above-average acidic level, suggesting near surface volcanic heat sources. Before it is possible to determine where it would be best to drill preliminary holes, it is considered necessary to conduct electrical resistance measurement surveys and geomagnetic surveys on new fluid samples.

7 Samoa Islands

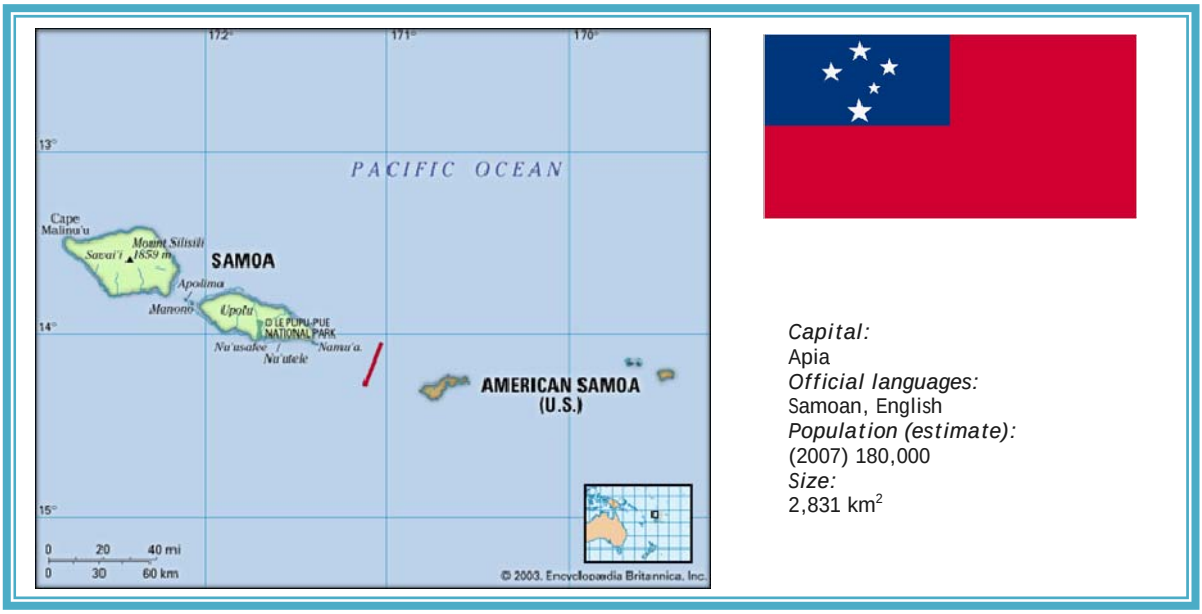


Photo 3. *Samoa Islands (Online Map/Still. Encyclopedia Britannica Online).*

There are no hot springs on the Samoa Islands, although three volcanoes have erupted within recorded historical times (1760, 1902, and 1905-1911). It is considered likely that there are geothermal hot spots below the surface, but further research is required to pinpoint them. Initially, water samples can be taken where possible for chemical analysis. In a report to the United Nations 20 years ago, Valgarður Stefánsson proposed that an extensive geotechnical survey be conducted on Savai'i, the largest of the Samoa Islands and the one farthest to the west. Data available from the World Bank states that geothermal energy is situated far from populated areas, but the actual location of the source is not specified. The United Nations showed interest in geothermal energy on Samoa in 1978, but the local government revealed at the time that the DSIR from New Zealand had considered utilisation of geothermal energy on the islands as not being financially feasible.

8 Solomon Islands

The market for electricity within the Solomon Islands archipelago is limited, except for the capital city of Honiara located on the northern side of Guadalcanal Island. Forty kilometres from Honiara, about five kilometres inland from the coast of Guadalcanal, are four thermal areas: Nggurara, Kunjuku, Saikotulu and Koheka. Another interesting geothermal site is located in Paraso Bay on Vella Lavella Island. There is also geothermal energy on the islands of Simbo and Savo. The depth of the geothermal field is unknown, and prior to drilling electrical resistance measurement surveys would be necessary (if it comes to that).

Capital:
Honiara
Official language:
English
Population (estimate):
(2007) 495,000
Size:
28,370 km^2

Photo 4. *Solomon Islands (Online Map/Still. Encyclopedia Britannica Online).*

8.1 Nggurara

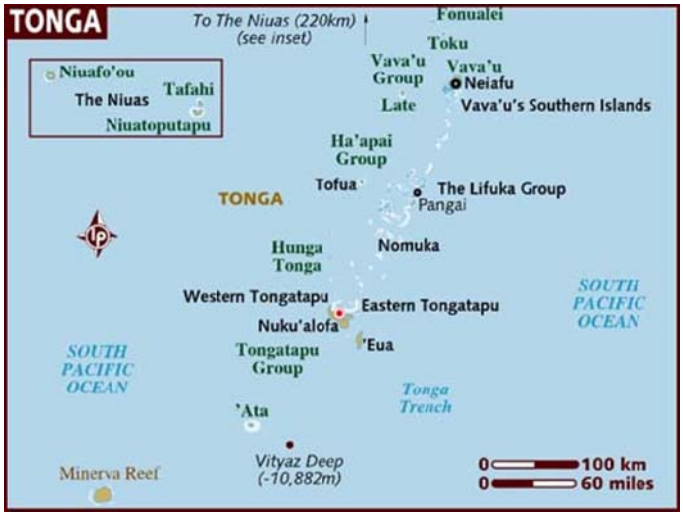
The Nggurara geothermal area is located in the northwestern corner of Guadalcanal Island. This area includes the Nggurara, Kunjuku, Saikotulu and Koheka hot springs with temperatures ranging from 38–63°C, but geochemical studies calculate the geothermometric equilibrium temperature at 160°C. Access to the site is somewhat difficult, which could have a negative impact on the feasibility of harnessing the geothermal energy for producing electricity for the capital of Honiara.

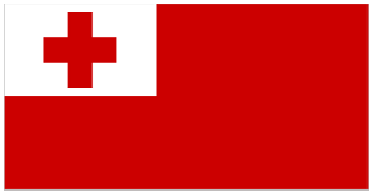
8.2 Paraso Bay

Heat from thermal springs in Paraso Bay on Vella Lavella Island have temperatures ranging from 32–96°C, considerable thermal water flow and significant quantities of hydrogen sulphide (H_2S) and carbon dioxide (CO_2). Geochemical studies indicate that the geothermometrically calculated equilibrium temperature is about 160°C, sufficient for binary power generation. Although the electricity market on Vella Lavella is small, the potential exists to develop industry that utilises electricity from a geothermal power station. It is estimated that Paraso Bay has the potential to generate 300 MWe, and discussions have been ongoing since 1979 to initially install a 10 MW station

(recommendation from the UK Institute for Geological Studies). A market for this production has not yet been found.

9 Tonga

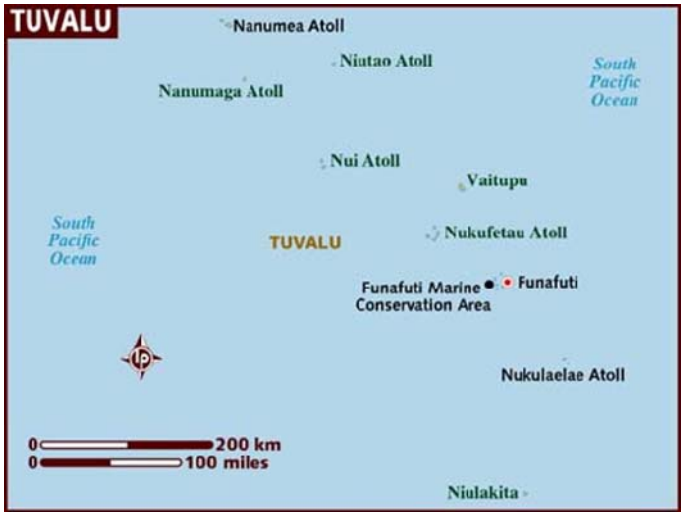


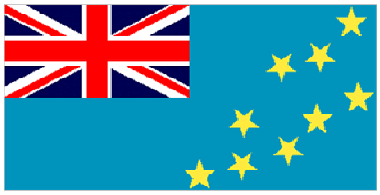


Capital:
Nukualofa
Official languages:
Tongan, English
Population (estimate):
(2007) 101,000
Size:
750 km^2

There are no known geothermal areas on Tonga, despite the existence of active volcanoes. In recent years, however, ocean hydrothermal systems from active submarine volcanoes have been discovered on the Tonga arc, which is a 425-km-long submarine ridge. Ocean hydrothermal systems are also found in the nearby Valu Fa Ridge. Eleven ocean hydrothermal systems have been found on these ridges emanating from seven volcanoes. Recently, temperatures of between 245–265°C were recorded at a depth of 385–540 m, but this volcano was quite far from Tonga Island, over 400 km, which is approximately one-fourth the distance to New Zealand.

10 Tuvalu





Capital:
Government is situated in Vaiaku, Fongafale on Funafuti
Official languages:
Tuvaluan, English
Population (estimate):
(2007) 9,700
Size: 26 km²

The Tuvalu islands have recently been in the news in connection with an impact assessment of rising sea levels, as the highest point on the islands is just five metres. If the sea should approach that level, all inhabitants would have to be evacuated. The same holds true for Maldeves and Kiribati.

11 Vanuatu

Capital:
Port Vila
Official languages:
Bislama, French, English
Population (estimate):
(2007) 226,000
Size:
12,190 km^2

There are a great many volcanoes situated along the Vanuatu archipelago in the southwest Pacific. The greatest power demand is on Efate, a circular-shaped island where most residents live. Electricity is generated at a diesel-fuelled power plant, where some of the generating units run partly on oil from coconuts, which are in abundance on the islands. Installed power at the Efate plant is 20 MW, and in the area are two prospective geothermal fields that have occasionally been under assessment since 1970. Both fields give reason for exploratory drilling. An appraisal conducted by PIRGADI recommends drilling two, 1800-metre-deep slim holes in each field. There is considerable thermal water flow from the fields, or about 320 L/s, most coming from Takara Springs.

Since a large portion of the power used on Vanuatu is for drying crops, it is considered sensible to utilise waste heat from thermal-generated electricity for such drying.

11.1 Takara Springs

Takara Springs is a geothermal area comprising about 405 hectares in the northeastern part of Efate with at least five, shallow thermal springs. At a depth of about six metres, it is possible to access thermal water that has a temperature approaching 78°C. Geochemical analysis indicates that equilibrium temperatures at an undetermined depth range from 160–170°C. Electrical resistance measurements taken in 1985–1986 by New Zealanders revealed a 100-km^2 low resistance area under Takara, and such a conclusion could either be an indication of a high-temperature area (higher conductivity in heat-metamorphised minerals), or a geothermal water system mixed with sea water (conductivity in sea salt).

11.2 Teouma River

Hot springs along the Teouma River in south Efate have temperatures ranging from 50–61°C. Geochemical studies by GENZL (Geothermal Energy New Zealand) from 1975 showed a geothermometric equilibrium temperature of over 200°C.

12 The energy market

The energy market in the South Pacific Islands is small and spread over a wide area. In comparison, electricity production in 2005 for all the islands was about half of the total energy produced that same year in Iceland (and since then electricity production in Iceland has increased significantly, much faster than on the South Pacific Islands). In addition, the population of the islands is about 30-fold that of Iceland. Power-intensive industry could, in some instances, thrive on the islands, in particular Papua New Guinea, as these are the largest islands and contain over half the population of the islands covered here. Geothermal energy is utilised in the gold mining industry on Lihir Island, but while mining is a profitable industry, there is controversy over whether mining in poor countries contributes to an increase in general prosperity. A factor such as this must be judiciously examined when considering the environmental impact, social infrastructure and political system of the respective country, for example the level of corruption.

13 Possible support of the IIDA in utilising geothermal energy

Geothermal energy is found widely in the South Pacific Islands, and it is conceivable that other considerations will determine events when the time comes to decide which islands shall receive support. Trust must exist, as well as the belief that collaborative efforts will prove beneficial for the public on the respective islands. With the current economic crisis created in part by rising oil costs, it is only natural to consider boosting the production of organic oil at home, assuming it does not result in a food shortage. Knowledge of local geothermal systems must be developed, along with slow and careful steps to implement growth in this sector. A Geothermal Training Programme would be very advantageous, as would good cooperation with “neighbouring” countries that have experience utilising geothermal energy, for example Indonesia, Japan and the Philippines. It is necessary to concentrate on ways to increase electricity consumption, since the market for home heating is limited. In recent years, there has been a positive trend regarding the cost of power stations that generate low-temperature electricity, and therefore it is not necessary to focus on major power plants that supply power-intensive industry.

1. Social Network: Conduct a survey to determine the islands that would be the most favourable to cooperate with in terms of the political and economic environment. There is also the need to assess the likelihood of achieving set goals. Initially, it would be preferable to have contacts in Papua New Guinea and Fiji.
2. Research: Further analyse the island selected in accordance with item 1 above, and organise a research expedition with the goal of finding useable geothermal energy. It would be preferable to implement this work either in cooperation or consultation with SOPAC.
3. Geothermal Training Programme: Arrangements made with students from the respective island to participate in the research project from the start in order to then conduct follow-up work. These students will have ongoing contact with the Icelanders after graduation, and assist in the development and possibly the operation of the geothermal power station. There is a certain lack of geothermal expertise at SOPAC, and this is an opportunity for improvement. The SOPAC headquarters are located on Fiji.

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Appendix

The South Pacific Islands Applied Geoscience Commission (SOPAC) is an independent, inter-governmental organization established in 1972 and financed by the following parties: Australia, Fiji Islands, Canada, France, Ireland, Japan, New Zealand, Office of US Foreign Disaster Assistance, Taiwan, the United Kingdom, the Commonwealth Secretariat, the European Union and certain UN agencies. The primary objective of SOPAC is to help improve the well-being of its member countries through the application of geosciences to the management and sustainable development of their natural resources. Specialists at SOPAC collect, and have specialised knowledge about, geotechnical data utilised in mining, exploiting drinking water, and in constructing power plants that utilise hydropower, ocean tides, solar energy, biomass and wind energy. Its headquarters are in Suva, Fiji Islands where about 60 experts and service providers are based. Each country has its own representative. With regard to special projects in the field of geothermal energy, SOPAC has approached companies within the U.S. Geothermal Industries Corporation (USGIC), which is a conglomerate of 16 U.S. companies formed in 1990 to work on multinational geothermal energy projects. The companies within USGIC can collectively undertake geothermal energy projects. For more information concerning the activities of SOPAC and USGIC, see Tables 3 and 4.

Table 3. *Members of the South Pacific Islands Applied Geoscience Commission (SOPAC) and contact information for each country: name, position and organisation. Countries marked with an asterisk (*) are associate members. Information derived from SOPAC's website in September 2008.*

Country name	*Name of contact*	*Position*	*Organisation/Agency*
Australia	James Batley	High Commissioner	Australian High Commission
Cooks Island	Mike Mitchell	Secretary	Ministry of Foreign Affairs & Immigration
Federated States of Micronesia	Peter M. Christian	Secretary	Department of Economic Affairs
Fiji Islands		Acting Director	Mineral Resources Department
French Polynesia (*)	Bruno Peaucellier	Head of International Affairs	
Gwam	Lorilee Crisostomo	Acting Administrator	Guam Environmental Protection Agency (GEPA)
Kiribati	Peter Tong	Permanent Secretary	Ministry of Fisheries & Marine Resources Development
Marshall Islands	Kino S. Kabua	Permanent Secretary	Ministry of Foreign Affairs

			and Trade
Naru		Secretary for Foreign Affairs	Department of Foreign Affairs
New Caledonia (*)	Yves Lafoy	Senior Advisor for Scientific & Technical Cooperation	New Caledonia's Office of Regional Cooperation and External Relations
New Zealand	Caroline MacDonald	Acting High Commissioner	New Zealand High Commission
Niue		Secretary to Government	Premier's Department
Pala	Temmy L. Schmull	Minister of State	Ministry of State
Papua New Guinea	Nellie James	Acting Secretary	Department of Mining Office of the Secretary
Samoa Islands	Aiono Mose Pouvi Sua	Chief Executive Officer	Ministry of Foreign Affairs and Trade
Solomon Islands	Tione Bugotu	Permanent Secretary	Department of Mines and Energy
Tokelau	Jovilisi Suveinakama	General Manager	Council for the Ongoing Government of Tokelau
Tonga	Sione Nailasikau Halatuituia	Secretary for Lands, Survey & Natural Resources & Surveyor General	Ministry of Lands, Surveys and Natural Resources
Tuvalu	Uale Taleni	Secretary	Ministry of Natural Resources
Vanuatu	Russell Nari	Director-General	Ministry of Lands and Natural Resources

Table 4. *U.S. Geothermal Industries Corporation (USGIC). List covering the 16 companies and their field of work (rough grouping) Most of these companies are very large and well known in the geothermal energy industry.*

Company name	*Address in USA*	*Field of work*
Air Drilling Service, Inc.	Houston, TX	Drilling
Ballew Tool Company	Cobb, CA	Drilling – services
Barber Nichols Eng. Co.	Arvada, CO	Engineering
Bibb and Associates, Inc.	Pasadena, CA	Engineering
Dames and Moore	San Francisco, CA	Engineering
Baker Hughes INTEQ	Santa Rosa, CA	Drilling technology
Geothermal Development Associates	Reno, NV	Geothermal power stations
Geothermal Management Co., Inc.	Frisco, CO	Consulting
Geothermal Power Company, Inc.	Elmira, NY	Turbines
Geothermex, Inc.	Richmond, CA	Consulting/services
Drill Cool Systems, Inc.	Bakersfield, CA	Drilling – services
Nabors Industries	Houston, TX	Drilling
Ormat, Inc.	Sparks, NV	Geothermal power stations
SAIC	San Diego, CA	Technical solutions
Energy & Geoscience Institute	Salt Lake City, UT	Research
Williams Tool Co., Inc.	Fort Smith, AR	Drilling technology