Decreasing Reliance on Fuel and Enhancing Renewable Energy-Based Electrification in the Small Island State of Tuvalu

The Tuvalu Solar Power Project

What is the e_8?

The e_8 – which comprises ten leading electricity companies from the G8 countries – promotes sustainable energy development through electricity sector projects and human capacity building activities in developing nations worldwide.

Mission Statement

The mission of the e_8 is to play an active role in global electricity issues within the international framework and to promote sustainable energy development. This diverse international group offers electricity sector skills and practical competencies in electricity generation, transmission and distribution. With international field-proven expertise in the planning, management, design, operation and maintenance of energy facilities, member companies assist and share their know-how in the effective implementation of sustainable energy development with counterparts in developing and emerging countries.

e_8 Member Companies

American Electric Power
United States

Duke Energy
United States

Électricité de France
France

ENEL S.p.A.
Italy

Hydro-Québec
Canada

JSC "RusHydro"
Russia

Kansai Electric Power Company, Inc.
Japan

Ontario Power Generation
Canada

RWE AG
Germany

Tokyo Electric Power Company, Inc.
Japan

Content

Message from Tuvalu's Minister for Public Utilities and Industries

Our beloved country Tuvalu, nine beautiful atolls, is now faced with the real likelihood that the rising tide caused by global warming may sadly submerge our low-lying nation. Tuvalu, in its Climate Change Policy, has appealed to the world as its people fight to be able to stay on the atolls and make every effort to remain above sea level rise. It is in such a context that Tuvalu has strongly committed to national and international actions and initiatives to fight global warming and its negative impact on development.

Tuvalu has continuously used diesel-based generators as a means of providing energy for the nation. The soaring international fuel prices in recent years, and forecasted for the years ahead, have given Tuvalu very little choice but to tum to renewable energy alternatives to diversify its energy supply sources. In particular, a country like Tuvalu, with sunlight almost throughout the year, has a high potential of using solar power as a source of energy.

Thanks to its understanding, funding and technical support, the e8 enabled Tuvalu to operate its first grid-connected solar power generation system. The system was successfully implemented by the e8 which did a tremendous job not only in developing the project and installing the system but also in carrying out maintenance work at the project site, Tuvalu's National Soccer Stadium. For that, we are most grateful.

This project was also partially funded through a grant from the Japanese Government. Taking this opportunity, I want to acknowledge the Government of Japan for its generosity in providing financial assistance to the project.

It is widely believed that primary energy resources continue to be depleted and fossil fuel is among them. It is therefore timely for nations of the world to look at alternative energy sources to minimise and slow down the use of fossil fuel, and to start developing renewable energies, including solar and wind power to cite a few.

We must be clear that, given the increasingly significant electricity demand in developing countries, there is going to be a growing market for renewable energy in those parts of the world. The e8 has already successfully demonstrated a pilot project in Tuvalu and it is my sincere hope that they continue to share their expertise with the rest of the world to enhance the use of renewable energies. It is also my wish that new technology developments lead to the design of solar power systems which would take up little space and best fit places like Tuvalu with very limited surface area.

Last but not least, may I express to the e8 and the Japanese Government our deepest gratitude for their great support, wishing them all the success in their future endeavours.

Hon. Kausea Natano

Tuvalu's Minister for Public Utilities and Industries

Like many Small Island Developing States (SIDS), Tuvalu, an archipelago consisting of nine coral islands in the South Pacific Ocean, has been heavily reliant on imported fuel for its diesel-based power generation system.

Given the recent soaring increase of oil prices on the one hand and, on the other, the significant potential for renewable (particularly wind and solar) energy sources in Tuvalu, the Government of Tuvalu and the Tuvalu Electricity Corporation (TEC) have expressed their will to switch from full reliance on increasingly expensive oil imports to an energy system based on the increased use of renewable energy sources.

In response to the conclusions drawn from a series of workshops organised jointly with the Pacific Power Association (PPA) on the potential of renewable energy in the Pacific region, the e_8 undertook the implementation of the first pilot model of a grid-connected solar power system on the island of Tuvalu.

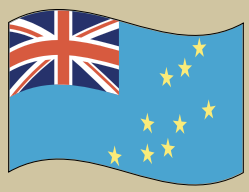
The project features a 40 kW grid-connected solar system that accounts for about 5% of Funafuti's (Tuvalu's capital) peak demand, and 3% of TEC's annual household consumption. The project will contribute to powering Tuvalu's households, healthcare facilities, small- and medium-sized enterprises and other local development infrastructure, based on a clean renewable energy source.

The e_8 Tuvalu Solar Power Project was inaugurated on February 21, 2008, in Funafuti. Upon commissioning, the project entered a two-year monitoring period during which the e_8 has been overseeing operations and maintenance activities to ensure the project's sustainability.

Tuvalu is one of the places on earth that are most vulnerable to the effects of climate change. The sea level rise associated with global warming threatens the very livelihood of the 12,000 Tuvaluans residing on the nine extremely low-lying coral atolls. The e_8 Tuvalu Solar Power Project sends a symbolic message about the importance of global, concerted and immediate action for the promotion of sustainable energy development worldwide and the fight against climate change.

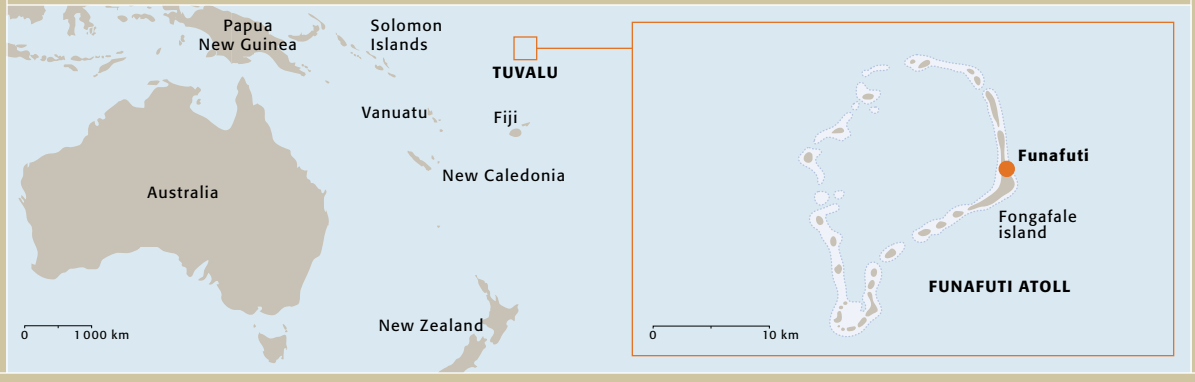
The Pacific Small Island Developing State of Tuvalu

Introducing Tuvalu



Located in the South Pacific Ocean between Australia and Hawaii, Tuvalu consists of nine atolls formerly known as the Ellice Islands. The country's total surface area is measured at 26 km² and the islands are characterized by a tropical ocean climate. Tuvalu's capital, Funafuti, is located on the island of Fongafale, a 3 km² small coral island in the Funafuti atoll. Funafuti, host city of the e_8 project, is equipped with a single airstrip, and home to the state's government office and to approximately half of Tuvalu's total population.

Location of Funafuti, Tuvalu



HIGH VULNERABILITY TO CLIMATE CHANGE

The damage resulting from global warming and sea level rise may not be a phenomenon of the distant future for the Pacific Island of Tuvalu. The tide has risen in recent years and seawater gushes forth from the ground during high tide season, invading fields and damaging crops. The beaches have been whittled away and coastal erosion has progressed to the point where plants along the seacoast have been devastated.

With the highest place in Tuvalu standing at only five meters above sea level, a majority at less than one meter high and an average rise of two meters, Tuvalu could eventually be submerged by the ocean if global warming and its impact on sea level continues on its present course. The islands sit upon a highly porous coral shelf which does not allow levees building to prevent submerging.

In 2000, the Government of Tuvalu, facing the potential reality that rising sea levels may render evacuation necessary, appealed to Australia and New Zealand to take in Tuvaluans if such conditions were to be confirmed in the future.

DEMOGRAPHIC AND SOCIOECONOMIC OVERVIEW

Tuvalu's population is mostly from Polynesian descent (96% of the population), with a small proportion from Micronesian descent (4%), and the languages spoken include Tuvaluan, English, Samoan and Kiribati (on the island of Nui).

The country consists of a densely populated, scattered group of nine coral atolls with poor soil, unknown mineral resources and few exports. Subsistence farming and fishing remain the country's primary economic activities. Public sector workers make up the majority of those employed, with about 15% of the adult male population working as seamen on merchant ships abroad, making remittances a vital source of income, and contributing around $4 million USD to the country's economy in 2006. Substantial income is received annually from the Tuvalu Trust Fund (TTF), an international trust fund established in 1987 by Australia, New Zealand and the United Kingdom and also supported by Japan and South Korea, which remains an important cushion for meeting Tuvalu's government budget shortfalls. Tuvalu also derives royalties from the lease of its ".tv" Internet domain name, with revenues of more than $2 million USD in 2006.

In an effort to ensure financial stability and sustainability, the government has been pursuing public sector reforms, including privatization of some government functions and personnel cuts. Growing income disparities and the vulnerability of the country to climatic change are among the leading concerns of the nation.

Impact of seal level rise

Coastal damage in Funafuti, Tuvalu.

Tuvalu Electric Power (TEC) Building, Funafuti, at low tide.

Tuvalu Electric Power (TEC) Building, Funafuti, at high tide.

POLITICAL SYSTEM

Tuvalu is a constitutional monarchy with a parliamentary democratic system. Member of the British Commonwealth, Tuvalu's head of state is Queen Elizabeth II who is represented by a governor appointed on the recommendation of the prime minister. Tuvalu's governor, since April 15, 2005, is Reverend Filoimea Telito.

The one-house parliament consists of 15 seats with a four-year term. The prime minister, who heads the government, is elected by and among the members of the assembly. The current prime minister in office since January 2007 —also acting as foreign minister— is Apisai Ielemia.

Top left: Sea coast landscape in Funafuti, Tuvalu. Top right: Children at the national soccer stadium in Funafuti, Tuvalu. Bottom: Airplane view of Funafuti, Tuvalu.

Tuvalu's Power Sector

The Government of Tuvalu has, in recent years, shown a strong interest in shifting the nation's energy policy and power sector initiatives towards the promotion of renewable energy sources and the diversification of the electricity production mix.

The State of Tuvalu emphasizes the need to develop indigenous forms of energy and endorses the importance of sustainable energy development and energy conservation.

Tuvalu Electric Power (TEC) Building, Funafuti, Tuvalu.

ENERGY POLICY

Tuvalu's electric power industry is under the supervision of the Ministry of Works and Energy, and the Tuvalu Electric Corporation (TEC) is the state-owned power utility which plans, operates and maintains the generation, distribution and sales of electric power on the archipelago's eight inhabited islands. TEC employs 40 people on the island of Fongafale on the Funafuti atoll, and 23 on regional coral islands.

Tuvalu's power sector is regulated by the Laws of Tuvalu and the Tuvalu Electricity Corporation Act enacted in 1990. The following subsectoral policy statements are from the country's latest energy policy:

- "The importance of establishing a reliable electricity supply to support socio-economic development cannot be understated… The provision of electricity both in the urban and rural areas is critical and given high priority in the government development plan (Te Kakeega II).
- The link between energy and the environment highlights the importance of having to place more efforts in the development of the renewable energy resources available in Tuvalu.
- The rising energy cost, together with the associated adverse impacts of energy production and use on the environment, necessitate policy responses aimed at the conservation and the efficient use of energy."

Providing Tuvalu's latest political orientation in energy and power-sector related matters, these policy statements reflect the government's clear commitment to the importance of renewable energies and have been translated into real commitments and initiatives including –but not limited– to the e_8 Solar Power Project.

NEW PERSPECTIVES

According to TEC's General Manager, Mr Mafalu Lotolua, "the development of renewable energy resources to diversify Tuvalu's energy mix offers some degree of energy security for the country". Renewable energy resources such as solar, wind and biofuel (mainly derived from coconut oil) provide a good prospect to broaden and diversify Tuvalu's energy supply resources.

Based on the e_8 pilot project's successful first year of operation, the Government of Tuvalu plans to expand solar power generation to the outer islands. The next project under study is a 46 kW system to be funded and implemented with the support of the Italian Government on the island of Vaitupu. While these projects generate a relatively small percentage of Tuvalu's total electricity supply, they are considered to be first steps towards a more substantial use of clean, indigenous energy.

Among many renewable energy development initiatives, Tuvalu is a participating country in the GEF-UNDP project "Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project" (PIGGAREP) and has provisions to follow-up on activities implemented under the Danish-funded Pacific Islands Energy Policy and Strategic Action Planning (PIEPSAP) project which funds a wind measuring programme. Wind measurement studies have been carried out in Funafuti for a period of two years and PIGGAREP is to provide financial support for further feasibility studies and assessment of wind power generation potential on the atolls.

Tuvalu is also part of the GEF Pacific Alliance for Sustainability (GPAS) programme under the "Low Carbon Energy Islands- Accelerating the Use of Renewable Energy and Energy Efficiency Technologies" initiative.

In 2008, New Zealand has offered to provide assistance to TEC for a 'Loss Reduction and Demand Side Management' project which would be administered by the Ministry of Economic Development and funded through the Government Agencies Fund.

To enhance the development of renewable energies in Tuvalu, funding requests have been submitted for the feasibility assessment for biofuel production and application, as well as for solar PV systems for the outer islands.

These various initiatives are consistent with Tuvalu's 2005-2015 National Strategy for Sustainable Development priorities and strategies (Te Kakeega II). These state the country's priority objectives of improving the well-being of the Tuvaluan people living on the outer islands and reducing diesel oil consumption by promoting the use of renewable energy resources through the implementation of cost effective, equitable, reliable, accessible, affordable, secure and environmentally sustainable energy systems.

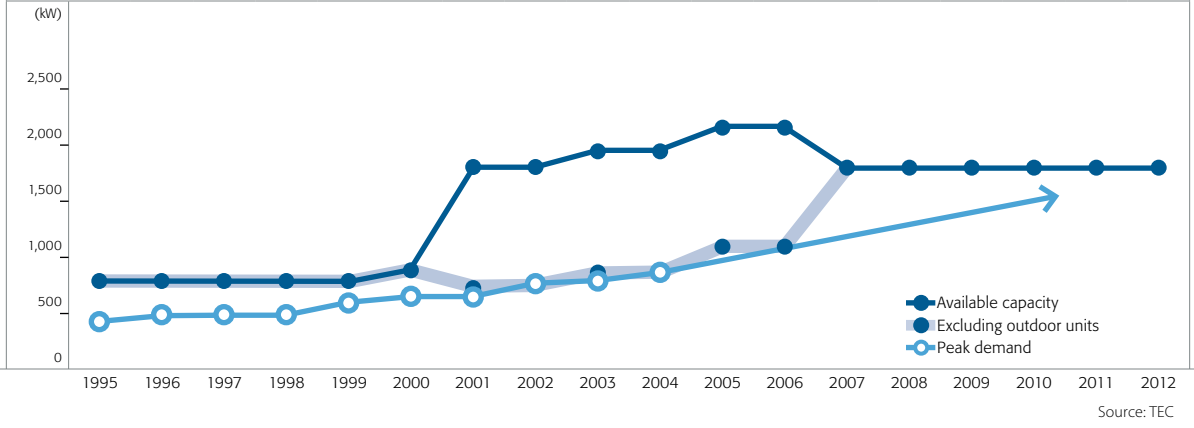
ELECTRICITY DEMAND AND POWER SYSTEM

While Tuvalu's power demand remains quite small (4,285 MWh in 2005 with a peak demand of 936 kW at the generators), peak demand tends to increase significantly when large-scale public or commercial facilities start operations. Peak demand increases are particularly notable on Fongafale Island where the population and major administrative functions are concentrated. According to TEC's analysis, the significant peak demand increases shown in the figure below are associated with the opening of a large store and new harbor illumination (1999), street light installation (2002) and the opening of new government offices and a general hospital (2004) in Funafuti.

Power is supplied by the Fongafale power plant (mainly fed by diesel power generators), Funafuti's power system's sole plant. Outdoor diesel power generators, with a total capacity of 1,005 kW, were set up on a temporary basis to meet the necessary demand during the construction of a new diesel power plant in 2006.

Funafuti's power system provides power to customers primarily through 11 kV cables from the Fongafale power plant via substations with 11 kV/415 V-240 V transformation equipment at 14 locations on the island. Up until the late 1970s, the country received aid from England for power-related infrastructure systems but, since 1982, power distribution installations have been mainly supported by the European Union (EU).

Power balance of Funafuti 's power system



Source: TEC

To address the issue of aging power plants and infrastructure, and with the support of the Government of Japan, a new power plant was constructed on Fongafale Island and the 11 kV power grid refurbished in December 2006. The new plant, consisting of diesel power generators with a total capacity of 1,800 kW (600 kW x 3 units), is expected to meet required capacity needs until 2012. In addition to establishing a reliable power supply system, these recent improvements are expected to promote the stability of key government functions and the economy at large, and to improve the standard of living of Funafuti's citizens.

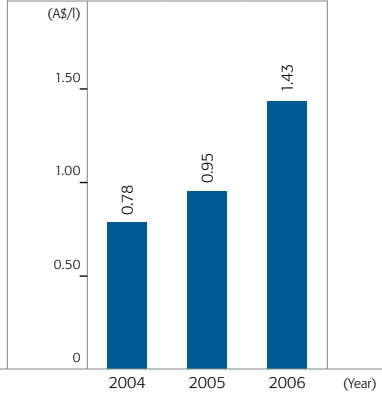
ELECTRICITY TARIFFS

TEC expects an annual average increase of 6.0% in peak demand in the future, due to the projected enhancement of harbor equipment (80 kW) and stadium lighting (18 kW), among other planned new installations. Starting from 2013, TEC foresees the need to carry out measures to avoid power supply disruptions as the load will reach its peak.

Even if TEC's existing infrastructure holds sufficient supply capacity, the price of electricity remains too expensive for the average citizen, at about $0.35 USD/kWh (2004). In fact, the real cost of electric power is 1.5 times higher than the price billed to customers. In addition, the skyrocketing prices of fuel in recent years, which doubled between 2004 and 2006, significantly affected TEC's and the government's financial situation, leading the latter to consider an increase of the electricity tariff to about $0.50 USD/kWh.

With such a financial strain, the Government of Tuvalu and TEC have expressed their need for a trigger that would help shift from full reliance on diesel for power generation to an hybrid system with renewable energy sources. TEC started to conduct studies to explore the potential and feasibility of solar and wind power generation, but no infrastructure project had been initiated prior to the e_8 project's inception in 2006, due to the lack of funds and experience.

Price of fuel for diesel generators in Tuvalu



1.00 Australian Dollar = 0.83 US Dollar, April 24, 2007
Source: TEC

The e8 Tuvalu Solar Power Project

Concept and Objectives

Pacific Island countries, and SIDS in general, have expressed a significant interest in renewable energy sources to both reduce CO_2 emissions and costs associated with fossil fuel imports on which their power generation systems depend heavily. The e_8 project in Tuvalu responded to the local government's stated political will to transform the existing power generation system towards a more sustainable one.

Signature of the Letter of Agreement (LOA) between the Government of Tuvalu, TEC and the e_8, June 12, 2007, Funafuti, Tuvalu.

Project team meeting involving TEC staff and e_8 experts.

INCEPTION

In response to a request from the Pacific Power Association (PPA), the e8 held a series of two workshops in 2005, designed to train engineers and technicians from PPA member utilities in the development of sustainable energy sites for wind, solar and micro-hydro power systems. These workshops aimed at enhancing the participants' technical capacity to design, procure, construct, operate and maintain renewable energy systems with a view to potential future sustainable energy projects. 37 engineers from 19 utilities attended the two workshops respectively hosted by the Marshall and Fiji Islands in March and November 2005.

The conclusions drawn from these workshops reflected a strong potential for enhancing renewable energy development in the Pacific region, with Tuvalu as the strongest candidate for a potential pilot project site. In collaboration with the PPA, the e8 undertook the implementation of the first pilot model of a grid-connected solar power system on the Island of Tuvalu.

In addition to the rising concern over the impact of climate change on the very livelihood of the people of Tuvalu and the subsequent symbolic commitment to renewable energy sources, Tuvalu has been faced with severe short- and medium-term socio-economic consequences due to the upsurge in international oil prices over the past years, leading to high electricity tariffs. As diesel-based power generation technology has reached a mature cost level and fuel prices are expected to remain high in the future, Tuvalu's electricity tariff is unlikely to decrease based on the current largely diesel-based power generation system. As a result, a significant part of the population remains excluded from affordable and reliable energy access.

The Tuvalu Government's commitment to the promotion of indigenous renewable energy resources, reflected in the country's most recent energy policy, shows that political will and economic rationale have created a momentum in Tuvalu to shift from full reliance on a diesel-based power generation system to a system based on the increased use of locally available renewable energy sources.

The e8, through the Tuvalu Solar Power Project, the island state's first grid-connected solar power system, provided the expertise and financial support to help trigger such a shift towards sustainable energy development in the archipelago, setting a model for the region as a whole.

e8 TUVALU SOLAR POWER PROJECT GOALS

- **Promote the use of renewable energy (RE) options in Small Island Developing States (SIDS);**
- **Provide momentum in Tuvalu for the shift from full reliance on diesel-based power generation to renewable energy sources;**
- **Transfer technological expertise in solar photovoltaic power generation to counterparts in the Pacific region and SIDS at large;**
- **Provide a pilot model of grid-connected solar power generation in the Pacific region;**
- **Reduce both CO_2 emissions and fossil fuel consumption;**
- **Send a symbolic message about the importance of global and concerted action for the promotion of sustainable energy development and the fight against climate change.**

PROJECT PRE-FEASIBILITY STUDY KEY RESULTS

The Kansai Electric Power Company (Kansai) and the Tokyo Electric Power Company (TEPCO), e_8 members from Japan, initiated a feasibility study for the implementation of a grid-connected solar power system pilot project in Tuvalu in August 2006. The following key findings were reported:

- The Government of Tuvalu and the Tuvalu Electric Corporation (TEC) strongly desired a trigger to shift from full reliance on diesel generation to an hybrid system with a renewable energy source.
- Wind and biomass were identified as holding some potential as renewable energy sources to be explored for electric power generation but solar power was identified to have the greatest potential in Tuvalu.
- The government offered a suitable location and sufficient space for the prospective pilot project's implementation.
- Considering the size of TEC's power system and the suggested project site, the project's capacity was estimated at 40 kW.
- Construction costs were estimated at about $412,000 USD and the unit cost per kWh for solar power generation was found to be almost equivalent to that of diesel power generation.
- The project was identified as an opportunity to shift from diesel-based to solar-based power generation with a potential to help decrease the price of electricity in the long term.

Based on these key and encouraging feasibility findings, the e_8 Tuvalu Solar Power Project was designed as a pilot model to facilitate and enhance sustainable energy development in Tuvalu and the Pacific region at large. In addition to the promotion of renewable energy sources in the region, the project was intended to send a symbolic message to the world about the importance of urgent action against climate change.

RENEWABLE ENERGY POTENTIAL IN TUVALU

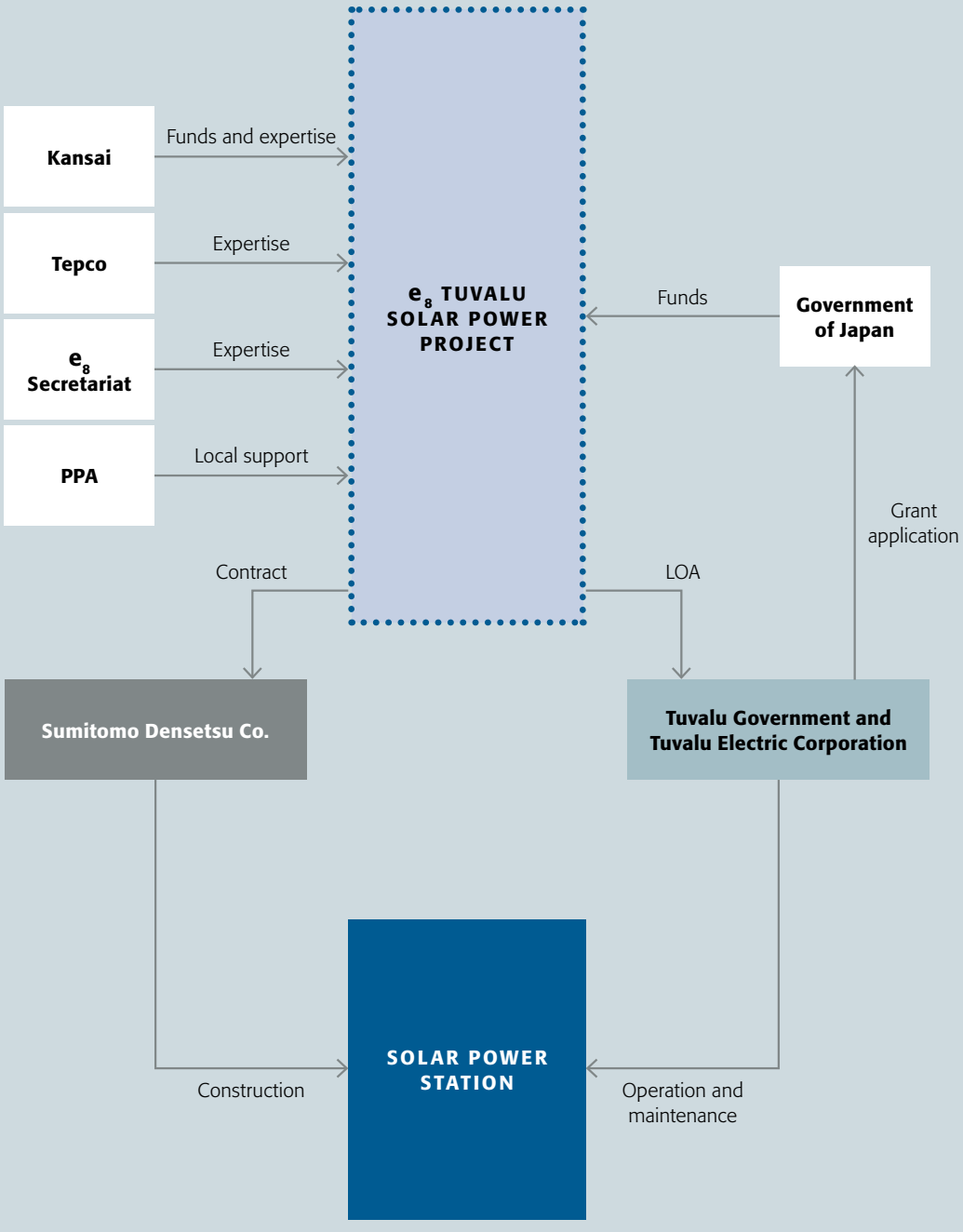
Resources	Comments
Micro-hydro	Hydropower resources are not available as there are no rivers.
Biomass	There is limited arable land and soil. Although a small amount of coconut trees and husks are available, it is mainly used for cooking.
Wind	Wind measurements showed sufficient wind power only between the months of November and March, and the lack of good wind synopsis points, due to the low-lying atolls, poses an additional challenge.
Tidal	The island sits on a highly porous coral shelf which does not allow storing significant amounts of water.
Solar	The rainy season lasts from November to April, but rain fall is not continuous. Located at 8 degrees south latitude, good solar radiation (more than 5 kWh/m²/day) is expected throughout the year.

Source: TEC, Global Environment Center Foundation.

e8 PARTICIPANTS AND PARTNERS

The project was mainly funded by Kansai and partially through a Japanese Government development grant. It was implemented in close collaboration with the Government of Tuvalu and the Tuvalu Electric Corporation (TEC) and benefited from the support of TEPCO and the Pacific Power Association. Upon commissioning in January 2008, TEC took over the facilities' operation and maintenance activities as per the Letter of Agreement (LOA) signed between the e8, the Government of Tuvalu and TEC.

THE TUVALU SOLAR POWER PROJECT STRUCTURE



BENEFITS AND SUSTAINABLE DEVELOPMENT FOOTPRINT

The e_8 project in Tuvalu is a small-scale solar power system model. It was designed as a blueprint to pave the way for similar projects to help enhance the use of locally available renewable energy sources and reduce the reliance on fuel for power generation in Tuvalu and the Pacific region. The project helped trigger and materialise Tuvalu's political will to move towards renewable energy-based power generation. It also directly contributed to build local institutional, human and technical capacity for the implementation of solar power systems by sharing knowledge and expertise with TEC's engineers and management team, and with other relevant governmental institutions' staff.

As the cost of solar power technology, which has not reached an optimal competitive level yet, continues to decrease over the next decade, the spread of grid-connected power systems holds the potential to decrease the price of electricity in Tuvalu and the Pacific region. This, in turn, could considerably contribute to improving the local communities' access to affordable and reliable energy services, as well as their income and standards of living in the long term.

Even though the e_8 Solar Power Project in Tuvalu only represents 5% of Funafuti's peak demand in capacity, it has reduced Tuvalu's consumption of generator fuel by about 17,000 litres in its first 14 months of operation. In the process, the project has reduced the risk of diesel spills around the archipelago and the nine atolls' carbon emissions by 50 tonnes, contributing to the protection of the Islands' environment and population from the adverse impact of emissions and fuel-related pollution.

Children in Funafuti, Tuvalu.

Funafuti's national soccer stadium and playground.

Project Management

The e8 Solar Power Project in Tuvalu was implemented under the leadership of e8 member Kansai Electric Power Company from Japan. The project management team was composed of internationally experienced engineers and experts whose knowledge of the Pacific region and long-standing experience in the implementation of renewable energy projects in developing countries around the world guaranteed the successful implementation of the project throughout its development stages.

Construction material transportation on site.

Technical staff meeting at the project site.

FINANCIAL SCHEME

The project was implemented based on a donation-type financial model, whereby the $410,000 USD project cost was financed through an e_8 donation (75%), supplemented by a Japanese Government grant. As per the Letter of Agreement signed by the e_8, the Government of Tuvalu and TEC in June 2007, the facility's ownership, operations and maintenance (O&M) activities, and related costs, were fully transferred over to TEC upon commissioning.

ENVIRONMENTAL IMPACT ASSESSMENT

The main environmental risk typically associated with solar power technology projects is related to the use of lead storage batteries. The Tuvalu project's system was designed to be integrated with TEC's existing grid, avoiding the use of lead storage batteries and their adverse impact on the environment.

Albeit minor, the following environmental risks were identified and addressed accordingly throughout the projects' implementation phases in order to minimise any potential negative impact on Tuvalu's fragile environment:

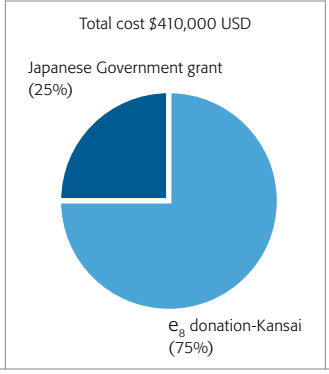
Alien organism contamination Alien organisms, adhering to transportation containers when parts and materials are imported, could possibly have an impact on Tuvalu's fragile ecosystem. Countermeasures, including extermination of potentially harmful insects and species, were undertaken when dealing with imported parts and materials.

Construction waste Tuvalu has no facilities for waste disposal. In order to minimise the amount of waste generated by the project's construction, wooden containers were used and the quantity of material precisely calculated in advance to minimise the amount of material waste.

Flooding Given the solar panel installation's surface area, an important level of water could flow into the drainage ditches at times of heavy rainfall. Flooding was taken into account when engineering the installation's drainage systems during the construction phase.

Noise and light The characteristic noise produced by solar inverters and the light reflected by the panels could disturb nearby residents. The consent of local communities living near the construction site was obtained prior to the project's implementation.

Project funding structure



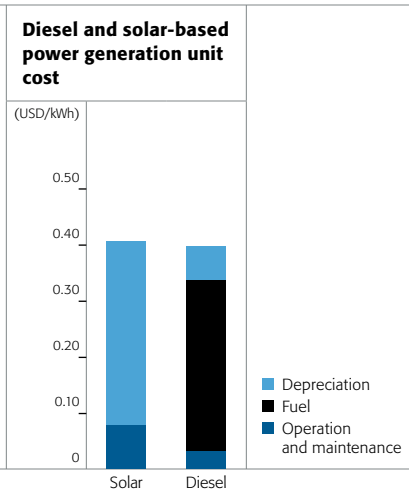
Construction material container transportation at the Funafuti harbour.

DIESEL-SOLAR COMPARATIVE GENERATION UNIT COST

Based on power generation unit cost per kWh, solar technology-based systems are typically not as competitive as diesel generators. However, in the case of small island states, heavily reliant on imported diesel to meet their energy needs, solar power generation can be a competitive alternative, particularly given the recent and foreseen rise in international oil prices. In the specific case of the e8 project, the estimated solar power generation unit cost is equivalent to that of diesel generators at about $0.4 USD per kWh.

DIESEL AND SOLAR-BASED POWER GENERATION UNIT COST

Item	Annual Cost (USD)	Unit Cost per kWh (USD)	Notes
SOLAR Annual production of electricity: 55,920 kWh			
Fuel and lubricating oil	0.00	0.00	
Depreciation	18,540	0.33	Economic life 20 years, salvage value 10%, straight-line method
Operation and maintenance	4,623	0.08	1% of the original facility costs and 720 person/hour
Total	**23,163**	**0.41**	
DIESEL Annual production of electricity: 3,700 GWh (total demand)			
Fuel and lubricating oil	1,139,304	0.31	fuel 0.26 l/kWh x $1.15/l, lubricating oil 0.002 l/kWh x $4.46/l
Depreciation	215,220	0.06	Economic life 15 years, salvage value 10%, straight-line method
Operation and maintenance	109,062	0.03	fuel 0.26 l/kWh x $1.15/l, lubricating oil 0.002 l/kWh x $4.46/l
Total	**1,463,586**	**0.40**	



Power generator control desk.

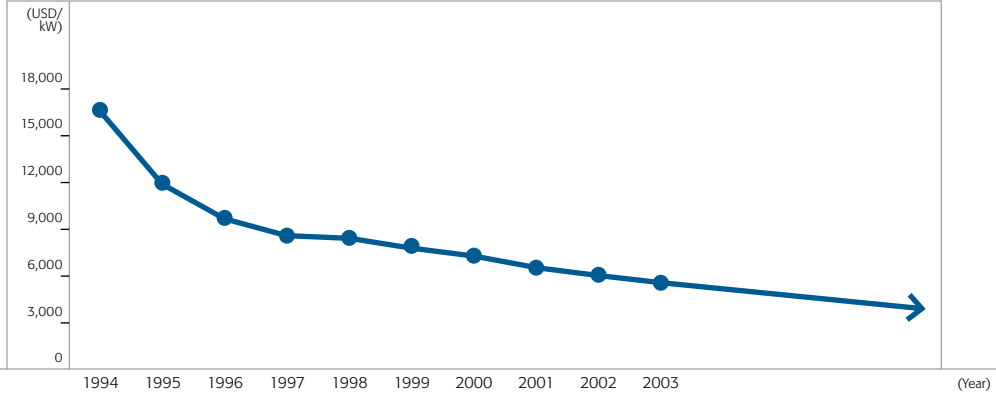
PROSPECTIVE ELECTRICITY TARIFF SCENARIO

Post-construction operations and maintenance activity costs remain extremely low in the case of solar power generation systems compared to diesel generation which requires expensive fuel. At a given power output level, solar power generation will significantly reduce TEC's equipment maintenance cash flow requirements compared to diesel power generation.

Taking into consideration the solar system's depreciation and given comparable unit price per kWh for both diesel and solar power generation, solar power generation cannot be expected to significantly reduce the price of electricity in the short term.

In the long term however, while no major reduction in the price of diesel power generators is anticipated, and while the price of oil is expected to continue to rise, the cost of solar power technology is expected to decrease as it has over the past decade. Such a trend could contribute to further enhancing the current political will to substitute diesel-based power generation with such renewable energy sources as solar power and, through that, to decreasing the price of electricity in the long term.

Solar power generation system construction unit cost



Source: New Energy and Industrial Technology Development Organization

Project Implementation

The 40 kW solar power system in Tuvalu was implemented over a period of 17 months, starting from the project's initial feasibility studies. The power system's construction was carried out by the Japanese Sumitomo Densetsu Company, under the leadership of the e8 project team and the steadfast support and involvement of TEC's staff.

Project implementation and construction phases.

IMPLEMENTATION SCHEDULE

After a year-long pre-feasibility and feasibility study phase initiated in September 2006 and followed by a three-month construction and testing period, the e_8 Tuvalu Solar Power Project was inaugurated on February 21, 2008, in Funafuti. The inauguration ceremony was attended by government officials, diplomatic representatives, dignitaries from the Tuvalu Energy Department and TEC, as well as high-level representatives from e_8 member companies.

Upon commissioning, the project entered a two-year monitoring period during which the e_8 holds the responsibility to oversee operations and maintenance activities to ensure the project's sustainability.

PROJECT IMPLEMENTATION SCHEDULE

Pre-feasibility and feasibility studies	September 2006 to September 2007
Construction	September to January 2008
Inauguration	February 21, 2008
Monitoring	February 2008 to February 2010

GENERATION CAPACITY

During the pre-feasibility study phase, a 50 kW solar panel installation system was initially proposed. However, given the designated site's surface area, the e_8 project team resorted to a 40 kW installation, including a 30 kW installation on top of the stadium stands' roof and an additional 10 kW solar panel installation on top of adjacent containers originally used for material transportation.

The project's 40 kW installation capacity accounts for about 5% of TEC's peak demand and can be considered to have been a successful trigger for a shift from full reliance on diesel generation to an hybrid system with a renewable energy source in Tuvalu. In fact, since the project's commissioning, the Government of Tuvalu has been looking into expanding the pilot project in Funafuti from 40 to 60 kW, and extending solar power to outer islands, starting in late 2009, with the construction of a 46 kW system to power Vaitupu's secondary school.

Representatives of the Government of Tuvalu, TEC and the e_8, at the project inauguration ceremony, Funafuti, Tuvalu, February 21, 2008.

Project inauguration ceremony, Funafuti, Tuvalu, February 21, 2008. (From left to right: Mr Ikoma, e_8 representative, Hon. Apisai Ielemia, Tuvalu's Prime Minister, Hon. Kausea Natano, Tuvalu's Minister of Public Utilities and Industries)

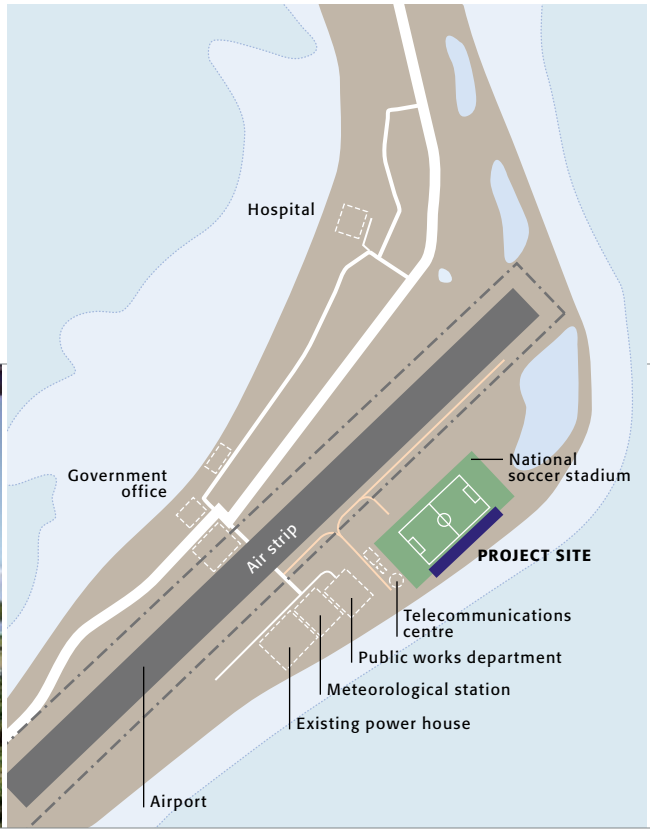
TOTAL POWER GENERATION

Annual power generation output was measured at about 56 MWh with a highly stable monthly average level throughout the year. In tropical places like Tuvalu, solar cells are exposed to high temperatures typically resulting in lower output of about 10% to 15% over rated values. In Tuvalu, despite the expected conversion efficiency drop due to high temperatures and efficiency loss from electric devices, the solar panels' operating rate was still measured at about 16%, a rate considered as good, given such temperature conditions.

PROJECT SITE

Solar panel installations require sites with no obstacles blocking the sunlight. The Government of Tuvalu, highly supportive of the project, offered a government-managed site, the nation's capital city's football stadium. The solar panels were installed on top of the spectators' stands' roof.

The e_8 Tuvalu Solar Power Project site.



Schematic view of the project site in Funafuti, Tuvalu.

THE SOLAR POWER GENERATION SYSTEM

DESIGN POLICY

The system selected was designed with key characteristics which would facilitate maintenance, encourage replicability and protect the environment.

Replicability
Standard equipment and materials were used to reduce construction costs and to enhance the project's replicability in Tuvalu and the Pacific region.

Maintenance
The system was configured to guarantee replacement in the event of equipment failure. Such measures as coating and sealing were taken to protect the system's equipment and devices against salt damage.

Environmental conservation
The solar system was connected to TEC's existing grid, thus avoiding the use of lead storage batteries and their adverse impact on the environment.

GRID CONNECTION

The following grid interconnection requirements were recommended during the project's implementation phase so as to avoid any potential negative impact of the solar power system on TEC's power grid.

Voltage fluctuation
Measures were taken to automatically adjust the power grid voltage using phase reactive power control, if voltage in the power grid was to rise, to limit values due to current from the solar power station.

Instantaneous voltage drop
To limit instantaneous voltage drop to a range of 10% of the rated voltage, self-exciting inverters were recommended.

Higher harmonics
According to Japanese Industrial Standards (JIS C 61000-3-2: Harmonic current generation limit value), the inverters' harmonic outflow current value (including filters) should not represent more than 5% of total current distortion and no more than 3% of individual current distortion. The use of electrical appliances compliant with such standards was recommended.

LONG-TERM EQUIPMENT MAINTENANCE

Given Tuvalu's tropical climatic conditions and their potential adverse impact on the system's installations, long-term maintenance measures were taken to ensure the equipment's durability and the solar system's operating efficiency over time.

Salt damage and high ambient humidity
Equipments were waterproofed and fitted with filters to prevent water and salt corrosion expected from high humidity and salt exposure, given their proximity to the sea.

Typhoons and heavy rain
Robust frames and panels were used and positioned in a way that minimises the wind-catching surface area resulting in air holes or impasses. To counter potential damage from heavy rains, the inverters' containers were heavily waterproofed.

Lightning
Because of the coral terrain, ground resistance could not be reduced sufficiently, and lightning arresters had to be installed in the main and control circuits.

Strong ultraviolet radiation
Intense ultraviolet radiation causes the solar cells' semiconductor crystal to deteriorate, significantly reducing conversion efficiency over time. To address that, the solar panels were coated with a film that filters ultraviolet radiation.

Lessons learned and success factors, in a nutshell

Monitoring reports from the project's first 15 months of operation showed flawless operations and maintenance activities under the leadership and supervision of TEC's staff.

The project's management team, leading the successful implementation of Tuvalu's first grid-connected solar power system from inception to commissioning, has reported the following lessons learned and success factors:

LESSONS LEARNED

- The implementation of solar power systems on remote islands requires longer time estimation and strong logistical management (i.e construction material transportation arrangements to the island etc.).
- Preparatory survey prior to construction needs to be very precise to minimise costs associated with over- or under-estimations leading to additional and expensive material transportation.
- Temperature control in the inverter room needs close monitoring in tropical locations like Tuvalu to avoid significant drops in operating rates due to high temperatures.
- Facilities' resistance against salt and water corrosion damage must be addressed during the construction phase and closely monitored upon commissioning.

KEY SUCCESS FACTORS

- Response to local needs and use of available resources.
- Strong local political momentum to introduce renewable energy sources.
- Support of key local actors (Tuvalu Government and Tuvalu Electricity Company).
- Technical training and monitoring.
- Use of standard and cost-competitive equipment.
- Built-in replicability potential.

Human Capacity Building Activities

Pacific Island countries are facing the direct effects of global warming as well as the rapid increase of oil prices, both of which are urgent issues influencing these nations' core development strategies and policies. Power utilities from countries in the Pacific region are highly interested in renewable energy sources to both reduce CO_2 emissions and the costs associated with current diesel-based power systems.

In addition to the Tuvalu pilot project, the e_8, on the strength of its members' vast and international expertise and in collaboration with key regional associations, has implemented human capacity building (HCB) initiatives with the objective to build the local expertise and technical know-how needed to enhance renewable energy power in the Pacific region.

PPA-e_8 photovoltaic systems workshop, Majuro, Marshall islands, April 2008.

THE PPA-e8 PHOTOVOLTAIC SYSTEM WORKSHOP SERIES

The e8, in partnership with the Pacific Power Association (PPA), implemented a series of technical workshops, targeting engineers and technicians from PPA member utilities, with the objective to enhance local capacity and technical know-how for the implementation of grid-connected and stand-alone photovoltaic (PV) systems. The initiative builds on an initial workshop on renewable energy options, delivered jointly by PPA and the e8 in March 2005, which revealed local interest in and potential for solar energy options in the Pacific region.

The initiative's first workshop, targeting electricity utilities from Northern Pacific Islands, took place in Majuro, Marshall Islands, from March 31 to April 11, 2008. The two-week workshop brought together 20 participants from ten different utilities, who received technical and hands-on training in the design, procurement, construction, operation and maintenance of PV systems. Utility engineers from the Marshall Islands, Palau and the Federated States of Micronesia took part in the training.

The second workshop, targeting Southern Pacific Islands utilities, took place from November 3-14, 2008, in Nadi, Fiji, and hosted a total of 18 engineers from nine utilities from the Island States of Cook, Fiji, Kiribati, Niue, Papua New Guinea, Samoa, Solomon, Tonga and Tuvalu. The participants attended lectures and took part in hands-on technical training sessions on a daily basis for the duration of the workshop.

This joint PPA-e8 HCB initiative has been particularly timely and well received in the Pacific region as many of the participating utilities are in the process of implementing country-wide electrification programmes based on PV systems, a wide-scale initiative subsidised by the European Union and other donor agencies.

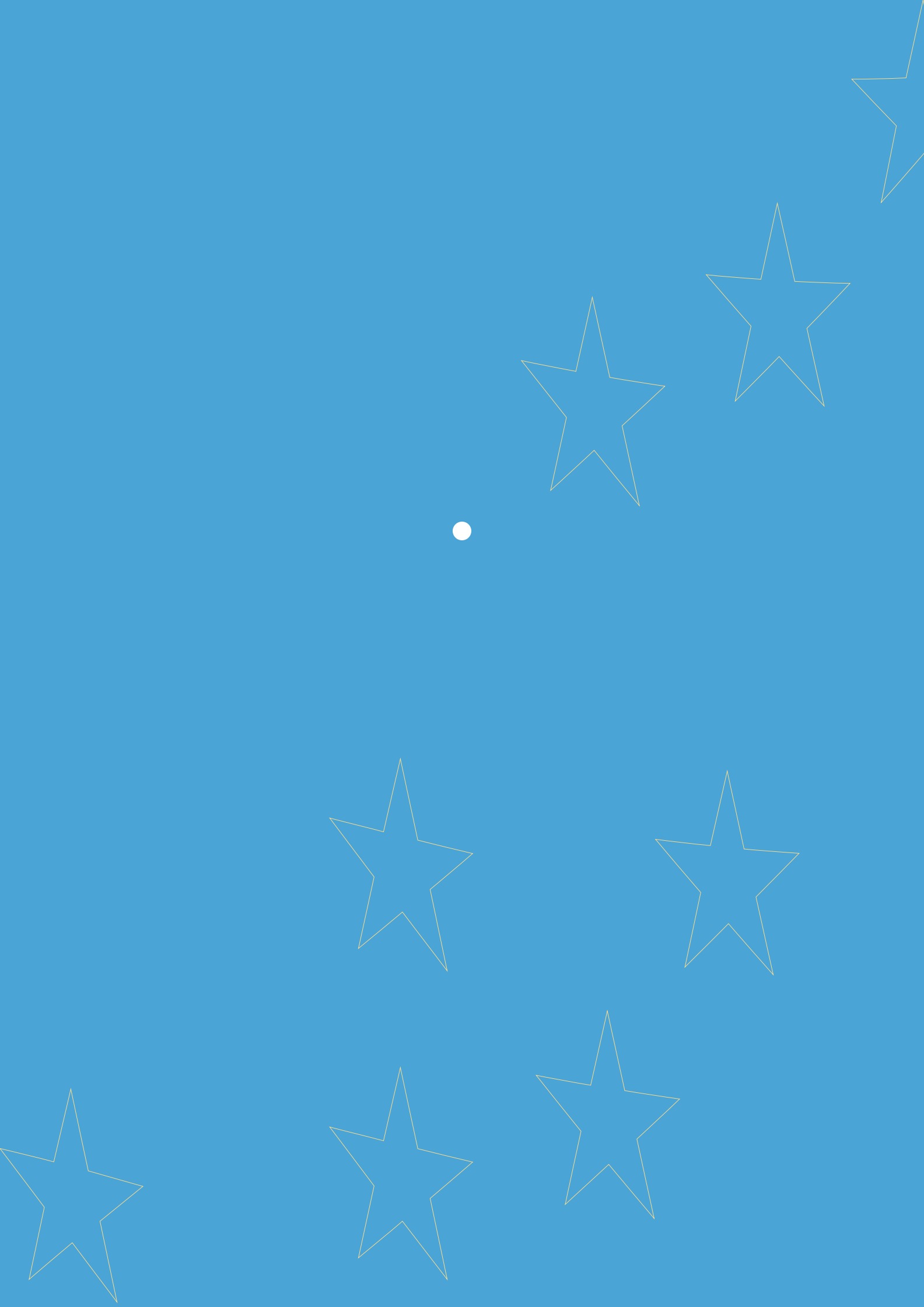
PPA-e8 photovoltaic systems workshop, Nadi, Fiji, November 2008.

The e_8 Solar Power Project in Tuvalu is an important step towards the country's stated development strategy of achieving socio-economic development and energy security while diversifying the energy production mix and protecting the environment. The pilot project was a trigger for the Government of Tuvalu and the Tuvalu Electric Corporation to integrate the use of locally available renewable energy sources in the country's power policy and electricity production portfolio.

The e_8, through technology transfer, technical knowledge and expertise sharing in this project, contributed to building local capacity for the implementation, operation and maintenance of solar power systems in Tuvalu and the Pacific region. In 2009, a year after the e_8 project's commissioning, the Government of Tuvalu announced its intention to expand the project's original capacity from 40 kW to 60 kW and to replicate the implementation of similar solar systems in outer islands.

The Tuvalu Government's strong political commitment to the implementation of this unprecedented solar power project sends a powerful symbolic message to the world as the effects of climate change on small islands states become alarming. As governments around the world prepare the negotiations towards a new international agreement on climate change, Tuvalu's efforts to promote the use of renewable energy sources set an example for the world with regard to the importance and urgent need to act on the implementation of sustainable energy development options and to jointly address the global challenge of climate change.

In line with the e_8 mission, the solar pilot project in Tuvalu provides a successful model of international collaboration which effectively helps advance the promotion of sustainable energy solutions, and contributes to the sustainable development goals of some of the most vulnerable developing nations in the world.



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