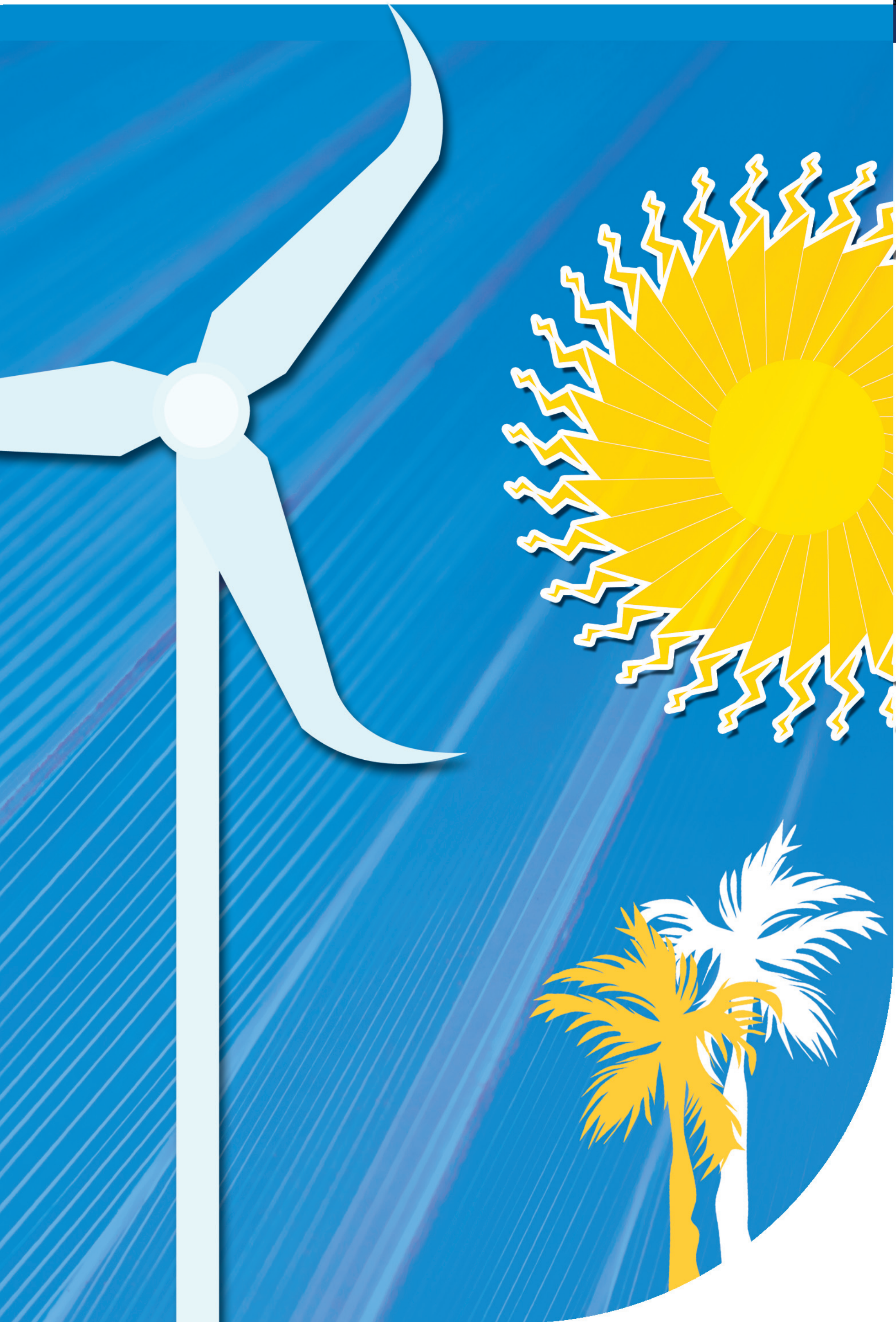
IRENA

International Renewable Energy Agency

KIRIBATI

RENEWABLES READINESS ASSESSMENT 2012



About IRENA

The International Renewable Energy Agency (IRENA) promotes the accelerated adoption and sustainable use of all forms of renewable energy. IRENA's founding members were inspired by the opportunities offered by renewable energy to enable sustainable development while addressing issues of energy access, security and volatility. Established in 2009, the inter-governmental organisation provides a global networking hub, advisory resource and unified voice for renewable energy.

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Exploring sustainable and secure pathways towards energy independence

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List of Acronyms

ADB	Asian Development Bank
ADO	Automotive Diesel Oil
AUD	Australian Dollar (currency)
CIA	USA Central Intelligence Agency
CNO	Coconut Oil
DC/DC	Direct Current to Direct Current
EEZ	Exclusive Economic Zone
ENSO	El Niño/El Niña Oscillation Cycle
EPU	Energy Planning Unit
EU	European Union
GDP	Gross Domestic Product
GWh	Gigawatt-hours (thousands of MWh)
IC	Island Council
IRENA	International Renewable Energy Agency
JICA	Japan International Cooperation Agency
KCMCL	Kiribati Copra Mill Company Ltd.
KIT	Kiribati Institute of Technology
KOIL	Kiribati Oil Company
KSEC	Kiribati Solar Energy Company
kWh	Kilowatt Hours (thousands of Watt hours)
kWp	Kilowatt-peak
LDC	Least Developed Countries (UN Designation)
LPG	Liquefied Petroleum Gas
ML	Megalitre (Millions of litres)
MLPID	Ministry of Line and Phoenix Islands Development
MPWU	Ministry of Public Works and Utilities
MT	Metric Tonnes
MW	Megawatts (millions of Watts)
MWh	Megawatt-hours (thousands of kWh)
NASA	USA National Aeronautics and Space Agency

O and M	Operation and Maintenance
OTEC	Ocean Thermal Energy Conversion
PEC	Pacific Environment Community
PIC	Pacific Islands Country
PIREP	Pacific Islands Renewable Energy Project
PWM	Pulse Width Modulation
PRIF	Pacific Regional Infrastructure Facility
PUB	Public Utilities Board
PVs	Solar Photovoltaics
PWD	Public Works Department
RD&D	Research, Development and Demonstration
RE	Renewable Energy
RERF	Revenue Equalisation Fund
RESCO	Renewable Energy Service Company
RET	Renewable Energy Technology
RRA	Renewables Readiness Assessment
SPIRE	South Pacific Institute for Renewable Energy (Tahiti)
SHS	Solar Home Systems
SOPAC	South Pacific Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USD	United States Dollars (Currency)
USP	University of the South Pacific
V	Volt (Electrical Measure)
WB	World Bank
Wp	Watts peak (Solar Photovoltaics)

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Comments or questions about this Renewable Readiness Assessment report can be sent to ychen@irena.org or to secretariat@irena.org.

Foreword

Energy independence has been a dream we have been pursuing for decades, as it is the foundation to our vision of providing "available, accessible, reliable, affordable, clean and sustainable energy options for the enhancement of economic growth and improvement of livelihoods in Kiribati." The recent surge in prices of energy commodities has only strengthened the need for energy independence and the link between secure supply of affordable energy for Kiribati and economic development. To achieve that, it is undeniable that renewable energy sources should have a major role to play.

The Renewables Readiness Assessment (RRA) process has been instrumental in identifying the gap that must be narrowed if the goal of being energy independent to be achieved. Even more importantly, the RRA can facilitate constructive discussions with bilateral and multilateral co-operation agencies, financial institutions and the private sector, leading to a truly joint effort to narrow the gap through actions developed and owned by Kiribati. The assessment can also provide directional guidance for all relevant stakeholders, in particular our development partners, to direct their efforts towards a common target.

Already, the impact of the intervention through the RRA has been felt within Kiribati. Following a recent RRA workshop, fossil fuel reduction targets were proposed for Tarawa, Kiritimati and the outer islands respectively. The proposed targets have been submitted to the Kiribati Cabinet for review and approval. If these targets are put in place, this will be a significant step for Kiribati's move towards energy independence.

I am confident that, with the concerted effort from the Kiribati government and people, and the co-ordinated support from the international development community, our dream of being an energy independent nation in the Pacific will soon come true. I am also personally proud to be part of the team contributing to the realisation of an energy-independent Republic of Kiribati.

Honourable Mr. Kirabuke Teiaua

Minister of Public Works and Utilities
Republic of Kiribati

Preface

Most islands around the world today are dependent on imported fossil fuels for the majority of their energy needs, especially for transport and electricity generation. For reasons of scale and isolation, energy infrastructure costs are higher, and the impact of oil price and supply volatility has been severe.

Kiribati is not an exception. The small island state has realised that its economic growth and development goals cannot be achieved if business continues as usual. A transition to a self-contained energy system, fuelled by indigenous resources, is needed with great urgency. With this goal in mind, Kiribati in 2012 conducted the Renewables Readiness Assessment (RRA) process laid out by the International Renewable Energy Agency (IRENA). This is a significant step in the long journey to energy independence.

The RRA is a central pillar of IRENA's work – a country-driven process aimed at providing the opportunity to initiate a national dialogue with all relevant stakeholders in order to pinpoint renewable energy drivers, comparative advantages, and areas requiring improvement, in order to determine the concerted actions needed to enable the development and scale-up of renewable energy. IRENA, with a mandate from its global membership to promote the adoption and sustainable use of all forms of renewable energy, is proud to support the RRA process for Kiribati by facilitating the country's dialogue with key international stakeholders such as the World Bank, Asian Development Bank, Secretariat of the Pacific Community and international research institutions.

As with all countries, this RRA reveals examples of good practices that could be shared with other countries, areas where readiness is high and other areas where readiness could be improved in the short- to medium-term, under initiatives led by Kiribati. The report now presented focuses on these actions. I hope that completing the RRA will enable the country to increase its deployment of renewables. We offer our continuing support, across all our functions and work programmes, to Kiribati in implementing the actions identified.

Last but not least, I would like to express my gratitude for the strong and solid support received from Ministry of the Public Works and Utilities of Kiribati over the course of conducting the RRA pilot project in Kiribati. I am also encouraged to see that the RRA process succeeded in mobilising active participation and contributions from the international community, including the World Bank Group, the Asian Development Bank, Secretariat of the Pacific Community and Germany's Agency for International Cooperation (GIZ). In addition, various stakeholders within Kiribati provided enthusiastic and serious engagement, without which the process could not have delivered the desired results. I therefore express my appreciation to all participants in the process and encourage them to continue their valuable work.

Adnan Z. Amin

Director General, IRENA

Executive Summary

The report serves to document the process of applying the RRA methodology to Kiribati. It includes reviewing the energy sector in relation to the development of renewable energy sources in the country, describing how the RRA workshop in Kiribati contributes to the development of an action plan to scale up the deployment of renewable energy sources in Kiribati, and articulating the actions identified into a structured portfolio.

BACKGROUND

Kiribati is a Pacific Island country in the central Pacific Ocean. In 2011 its population was recorded at 103 058 persons on a land area of slightly more than 800 km^2 spread over 32 atolls and one raised coral island. Kiribati is one of the UN-designated Least Developed Countries and has an annual per capita gross domestic product (GDP) of around USD 1 730. About 44% of the population lives on densely populated Tarawa, the capital island. They participate fully in the money economy. On most other islands a subsistence economy dominates with only limited participation in the money economy. The national economy depends on income from the Banaban Trust Fund, established through revenue gained by the mining of phosphate from Banaba, licensing of foreign fisheries, remittances from workers overseas, and international develop-ment partner donations. High imported fuel prices have been a major burden on the economy with over 21 million litres of annually imported fuel, accounting for the bulk of the national import budget. This has led to a government decision to reduce imported fuel dependency through the increased use of renewable energy for power generation and transport.

The National Energy Policy of 2009 is the primary reference document for energy in Kiribati. Tarawa is urbanised with grid-delivered electricity available to most residences, with a substantial public and private land transport component of energy end use. Tarawa uses the bulk of the energy imported to Kiribati. Kiritimati is the largest island in Kiribati, but has little land transport. Instead, most residents are connected to one of the small diesel powered electricity grids located on the island. Other outer islands, where about half of the population resides, have no public electricity grids and electricity access is mostly through small-scale solar energy harvesting systems on houses known as solar home systems (SHS) and public meeting facilities.

RENEWABLE ENERGY SOURCES

Solar photovoltaic (PV) energy is the most commonly used renewable resource in Kiribati, with over 2 500 solar installations of various types deployed around the country. The solar resources are good, at around 5.5-6 kWh/ m^2/day, with only mild seasonal variation. With a high percentage of the islands covered by a coconut tree canopy, the possibility of using coconut oil (CNO) to replace imported diesel fuel is also very good. Wind energy appears to be a useable resource as well, although it is at the low end of the useful wind speed spectrum for economic energy development. For the future, ocean energy – both wave and ocean thermal energy conversion (OTEC) – may become useful but currently tapping those resources remains at the technical development stage.

Kiribati has been successfully using solar PV for outer island electrification for over 20 years. The government owned Kiribati Solar Energy Company (KSEC) has a pool of technicians skilled in the installation and maintenance of off-grid solar power systems. The KSEC is currently managing over 2 000 solar home installations and public building solar installations on 18 islands. Solar pumping for village water supply is also a major use of renewables on outer islands.

POLICY AND PLANNING BACKGROUND

In Kiribati, the Ministry of Public Works and Utilities (MPWU) and the agencies under its management have primary responsibility for the energy sector. Other primary stakeholders include the Ministry of Finance, the Ministry of Line and Phoenix Island Development (MLPID) responsible for all government services on Kiritimati, the Kiribati Copra Mill Company Ltd. (KCMCL) that produces CNO and the Kiribati Copra Cooperative Society (KCCS) that produces copra.

To help develop solid goals and an action plan to maximise the economic use of Kiribati's renewable energy resources, IRENA was requested to assist through a Renewables Readiness Assessment (RRA). The RRA was carried out in October 2012 and its key issues and results are presented in the table on facing page.

STRATEGY FOR FUTURE DEVELOPMENT

The initial approach for renewable energy to offset fossil fuels will be through grid-connected solar PV systems. Two projects are in the pipeline:

(i) 516 kWp of solar funded through the WB;

(ii) approximately 400 kWp of solar funded through the PEC Fund.

The combination of these two installations will bring the solar input close to the practical limit of acceptance by the Tarawa grid. Unless storage or special control systems are incorporated in later installations, there will be an increasing risk of inducing grid instability and power outages due to the rapidly varying input from the solar, should more solar PVs systems be installed. Included in the projects will be initial support for operation and maintenance and capacity building as needed to support

Issues discussed at the RRA and proposed actions are summarised in the following table:

Issues	Proposed Actions
Maintain the stability of the grid while allowing a high level of solar PV input	• Coordinate Kiribati's on-going solar initiatives supported by the World Bank (WB) and the Pacific Environment Community (PEC) Fund, so both take responsibility for their combined projects to prevent endangering grid stability. (This is underway with the WB, PEC Fund and Kiribati government working together to co-ordinate the projects). • Develop standards and guidelines for future solar PV grid-connected systems (underway with the assistance of the WB). • Investigate the appropriateness of privately-owned grid-connected solar PV. • Build capacity to manage grid stability with high levels of solar penetration (initial capacity building steps are expected to be components of both the WB and PEC Fund projects).
Develop CNO as a biofuel for power generation	• Prepare a CNO implementation plan for Kiribati's CNO biofuel development to determine the specific actions and timelines necessary to develop CNO as an acceptable diesel fuel replacement. • Establish fuel standards and a testing facility for CNO-based biofuel to be used for power generation and transport. • Develop mobile copra mills for use on Kiritimati and outer islands. • Have the Public Utilities Board (PUB) procure an electric power generator (genset), designed for use with CNO for base load generation. • Develop KCMCL testing facilities of biofuel for power generation.
Use of CNO as a land and sea transport fuel	• Trial of shipboard use of CNO through the use of a dual tank system. • Trials of blends of CNO and kerosene or diesel fuel for land transport. • Prepare an outer islands electrification implementation plan that only uses renewable energy. • Prepare a standard modular design and installation guidelines for solar powered mini-grids.
Off-grid electrification	• Develop a local off-grid electrification capacity building facility at the Kiribati Institute of Technology (KIT). • Provide for rehabilitation of existing outer island solar installations. • Determine how the KSEC can be institutionally strengthened.
Policy, legislation and regulation development to support renewable energy	• Establish a Kiribati National Energy Coordinating Committee (KNECC). • Review existing incentives, regulations, and policies relating to energy and propose changes where there are disincentives for renewable energy. • Prepare an "Energy Act" that fills the gaps in current legislations. • Review the KSEC business model.

the projects. To properly implement grid-connected solar, standards and regulations are being formulated with the support of the WB. IRENA offers to assist in the modelling of the grid to help plan for the integration of future grid connected solar.

For solar-based outer island electrification, an institutional structure like that of a conventional utility has been used successfully. This includes ownership of the capital equipment by the KSEC, a staff of technicians on the outer islands employed by the KSEC for all maintenance, and fees collected from customers based on the level of service rendered. This approach was instituted because individual solar equipment purchasers failed to properly install and maintain the solar equipment. The utility approach provided Kiribati with unparalleled levels of SHS reliability and long life during the first decade of its use.

Lessons learned through this process include:

1. A continuing training process is necessary.
2. Middle-aged persons generally do best as local technicians.
3. High quality equipment specifically designed to work in the difficult environment of Kiribati is essential.
4. Simplicity of maintenance is vital.
5. Spare parts inventory control is very important.
6. Fees need to keep up with inflation.
7. Centralised administration does not work well when all activities are on outer islands.
8. Clear work guidelines are needed for the administration and technical activities of the KSEC.

Another success that Kiribati can claim is the local manufacture of SHS charge controllers and direct current to direct current (DC/DC) converters to operate radio from SHS batteries. No commercial charge controllers were available that were suitable for the difficult atoll environment of Kiribati that could be locally tested and repaired. Therefore Kiribati chose to manufacture its own charge/discharge controllers based on a French design that was developed specifically for atoll island use. The 300 units manufactured and installed in Kiribati in 1994 provided highly reliable service. Their proper charge/discharge control task implementation is evidenced by the more than 10 years of average battery life for those installations.

Lessons learned in this process include:

1. High reliability charge controllers and DC/DC converters for SHS can be cost effectively manufactured by local technicians in the Pacific Islands.
2. Training for the manufacture of the devices need not be complex or expensive.
3. It is best not to use only one quality control step in manufacturing electronic devices and instead use at least two with an initial setting by one technician and a check by a second technician.
4. By using a design specifically created for the atoll environment and the end use, much longer service life and higher reliability can be achieved.
5. High reliability controllers result in longer battery life and lower life cycle costs.

The second major renewable energy source that is proposed for development is CNO for biofuel use. Kiribati remains one of the few Pacific countries still producing and exporting copra and coconut oil, though exports are much lower today than 20 years ago. To use CNO for power generation it was recommended by the RRA[1] that the new engine scheduled to be purchased by the PUB be of a type that is designed for dual fuel operation and can burn 100% CNO without problems. Also proposed is to convert inter-island ships to be able to use CNO when cruising yet switch to diesel fuel when the engine is at low loading. By blending with diesel fuel or kerosene, CNO can be used in unmodified diesel engines though there will need to be some additional refining beyond what is now the norm for the local mill product. For coconut production to increase to the level needs for a major reduction in fuel imports, a major replanting programme to replace senile low-productivity trees will be needed. The plans developed by Kiribati's Ministry of Agriculture are in place for starting replanting but funding is needed to carry out the plans.

Kiritimati Island is a special case with multiple small grids providing electricity to its approximately 5 000 residents. A power development plan for Kiritimati has just been proposed. It will connect most of the small grids that now exist into a single grid with generation support expected to be from solar, CNO and possibly wind.

Looking forward, the RRA is just the first step towards a comprehensive action plan to reach the goals of renewable energy set by the Kiribati government. As the lead agency in assisting Kiribati to reach their renewable energy goals, IRENA plans to assist in co-ordinating donor agencies and in attaining funding for projects. Furthermore, IRENA aims to aid in co-ordinating the efforts of the WB and the Pacific Environment Community (PEC) Fund to implement Kiribati's grid-connected PV projects in a way that will not adversely affect grid stability, drawing on experiences from other parts of the world and supporting Kiribati leaders' attendance of meetings and workshops where high level persons from around the world discuss the future of renewable energy and its implementation today.

In addition, IRENA sees many other areas to be effectively engaged. One example is in capacity building in Kiribati. This is an area where IRENA's support can be impactful if it is done well and where IRENA has the capacity to make a difference. IRENA hopes to work further with Kiribati to help develop the capacity to carry out the planning, implementation and management of the programmes that will be needed to reach its renewable energy goals. IRENA would work with partners on capacity building, as it has been doing in 2012, including the Secretariat of the Pacific Community (SPC), GIZ, Pacific Power Association (PPA) and Sustainable Energy Association of the Pacific Islands (SEIAPI). These organisations would facilitate a presence on the ground and provide long-term experience in the Pacific while complementing IRENA's technical and organisational capabilities.

Another important follow-up lies in setting targets for reducing fuel import dependence. Following the RRA, the Kiribati Energy Planning Unit (EPU) has prepared detailed targets for renewable energy development. Since the EPU also considers

1 The RRA brought in technical expertise provided by CNO expert Dr. Gilles Vaitilingom of Agricultural Research for Development, France. On the markets, there are a number of well-known manufacturers, including mainstream power generation engine manufacturers.

energy efficiency an important measure to reduce the consumption of imported fuels, the MPWU took advantage of the momentum from the RRA workshop and funded a third workshop day in order to begin development of an action plan for energy efficiency in Kiribati. From that effort, targets for energy efficiency improvements were also prepared. At present, the proposed targets have been submitted to the Kiribati Cabinet for final approval. It is expected that the national targets will soon be approved.

In order to reach the targets that are set, energy planning is crucial. It is a process requiring multi-stakeholder consultation and co-ordination, the capability of developing different energy scenarios, the human resources to develop a concerted plan and to implement it effectively, and all areas that can be assisted by IRENA. Kiribati will need to establish a national institution responsible to co-ordinate the different governmental agencies on energy related issues and strategy making. This may also present an opportunity for IRENA to provide support to Kiribati in terms of sharing the best practices of energy planning and also facilitating the set-up of such a co-ordinating entity.

I. Introduction

This section presents a snapshot of Kiribati's country profile, not only serving as an overall background in which the RRA was conducted, but more importantly, acting as an initial justification for why an RRA is necessary for Kiribati. With that, the objectives for the RRA pilot project in Kiribati were defined.

COUNTRY PROFILE

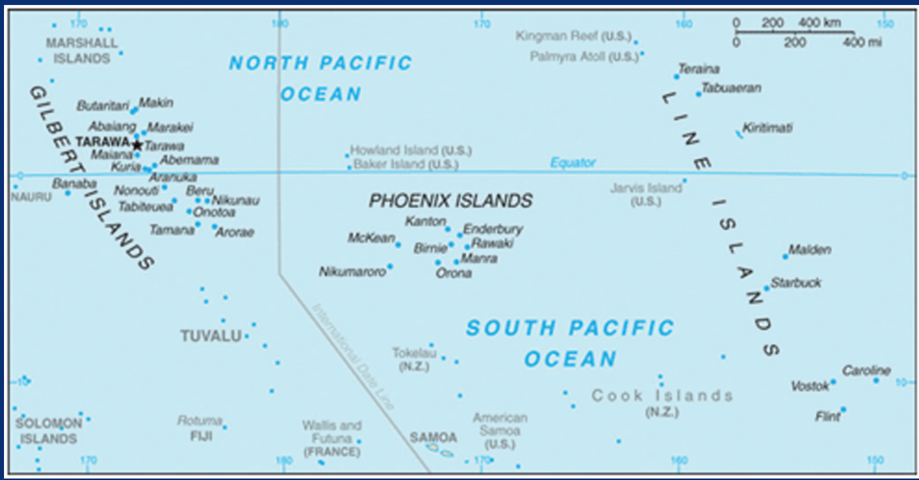
Geographically, Kiribati is an island country in the middle of the Pacific Ocean. It is spread over an area of 4 200 km by 2 000 km, with 32 atolls and one raised coral island (Banaba). The country straddles both the Equator and the 180° Meridian, making it the only country in the world to fall into all four hemispheres, i.e. northern, southern, eastern, and western[2]. However that huge area includes only about 800 km^2 of land area; the remainder is the vastness of the Pacific Ocean. This makes Kiribati not only far away from the nearest continents but also a widely scattered nation clustered into three groups of islands, as seen in Figure 1.

The principal island groups include: the Gilbert group to the west where over 90% of the population resides; the almost unpopulated Phoenix group to the south; and the sparsely-populated but growing Line group to the east. In 2010, about half of Kiribati's total population of 103 058 (2010 Census) lived on the capital island of Tarawa, in the Gilbert group. The dense and growing population of Tarawa has resulted in many problems with the supply of water, sanitation and energy. It is for this reason that the government has set a goal to both reduce the flow of people from the rural islands to the urban area of Tarawa and to encourage emigration to Kiritimati in the Line group, which is Kiribati's second largest population centre of around 5 000 people.

Since its independence in 1979, political stability has been a significant advantage of the country. The government is organised according to the Westminster format, with the president as the head of state. A unicameral legislature has 46 seats with 44 elected to four-year terms by popular vote. The attorney general is an ex-officio member, one representative is app-ointed to represent Rabi (the island in Fiji where most Banaba residents relocated after their island was mined out) and

2 https://www.cia.gov/library/publications/the-world-factbook/geos/kr.html

Figure 1 **Map of Kiribati and its principal group islands**



Source: CIA World Factbook

one other member is appointed. Today traditional authority remains a strong force, parti-cularly on the outer islands. On each of the outer islands, power is vested in an Island Council (IC), where typically elder men who represent the villages on the island govern through custom and tradition within the legal structure of the country.

Economically, Kiribati is listed as one of the world's Least Developed Countries by the UN. Since 1979 when the country's most marketable natural resource of phosphate from Banaba was mined out, the country's economy has been dependent on three major sources of income. These include the earnings from the Revenue Equalisation Reserve Fund (RERF) established in 1956 and funded by the revenue from phosphate mining; the licensing of foreign fisheries in Kiribati's huge Exclusive Economic Zone (EEZ); and remittances from overseas workers, who are mainly seamen on European vessels. Tourism is negligible due to the high cost of access and the lack of visitor facilities. Another contribution to Kiribati's GDP is from foreign financial aid provided by countries and regional organisations such as the European Union (EU), United Kingdom (UK), United States (US), Japan, Australia, New Zealand, Canada, and UN agencies. According to figures from the Ministry of Finance and Economic Development of Kiribati, the country's average trade deficit is in the range of USD 95 million per year with the deficit covered by the main sources of income, some agricultural exports and donations. In recent years, particularly since 2002, the real GDP growth has been low, estimated at 1.75% in 2011 (IMF) with a total 2011 GDP of around USD 178 million (WB), which works out to be about USD 1 730 per capita, one of the lowest in Micronesia and Polynesia.

According to an EU Country Strategy Paper and National Indicative Program for 2008-2013, in response to economic pressures, Kiribati cut its expenditures to reduce the overall deficit from 41.3% of 2004 GDP to 15% of the 2006 GDP. However, in a public sector dominant economy, the cut in public expenditure also meant less GDP to be generated. In Kiribati, nearly 80% of paid employment is provided by the government or through government owned enterprises. More than half of its GDP is generated from public sector expenditure, making the government not only the biggest employer but also the chief economic growth driver (ADB, 2009). With the underdeveloped private sector and low level of economic activities, it is difficult to attract private investment to escape from this scenario. This economic structure has put the country in a vulnerable position in a rapidly changing and increasingly globalised world.

The effect of high fuel prices is noticeable. Kiribati relies almost entirely on imported fuels for its power generation and transportation. Therefore the surge in fuel prices in the global energy commodity market has, in recent years, made fuel approximately 25% of the cost of all imports, meaning that less of Kiribati's national budget is available for non-fuel expenditures. As a result, fuel price increases have reduced resources needed for public services such as education, health and infrastructure development. It has also pushed electricity prices to a level among the highest in the region, ranging from USD 0.42/kWh to USD 0.73/kWh (MPWU, 2009). In this way Kiribati has been caught in a vicious cycle - a cycle that needs to be disrupted in order for the country's economy as well as its energy supply to develop in a sustainable fashion.

What alternative does Kiribati have then to imported fuels? The answer appears to be obvious, as the country has been utilising renewable energy resources for more than three decades with the continued support of the donor community. Nevertheless, to achieve the ambitious ultimate goal of being an energy independent country, there is a need for Kiribati to look carefully at where it is now and how it can reach the point at which it needs to be. To achieve this, a portfolio of actionable initiatives needs to be identified, developed and implemented in a clearly articulated way. This requires strategic thinking, which cannot be applied without a comprehensive assessment of the conditions for renewable energy deployment and development in Kiribati and in-depth multi-stakeholder discussions that pertain to the actions necessary to improve these conditions.

RENEWABLES READINESS ASSESSMENT

IRENA's RRA is designed to define a detailed list of criteria considered necessary for the on-going operation of existing renewable energy facilities and for further renewable energy development. Applying this framework to individual countries provides a comprehensive analysis of the presence or absence of enabling conditions for the development of renewables. Crucially, this analysis needs to take into account how the renewables policy of the country contributes to its national policy objectives. The RRA process also facilitates comparisons and case studies and enables the useful matching of attributes of renewable energy with opportunities for its deployment.

The RRA comprises a process and methodology that includes completing a set of templates and a final report. The RRA methodology covers all forms of energy services (transport, heat, electricity and motive power), and all renewable energy sources, with each country selecting those of particular relevance. The RRA also makes the applicant country's government a stakeholder in the process, as it is designed to be conducted by national governments, thereby allowing them to obtain a comprehensive overview of the conditions for renewable energy from their own national perspective. Under the RRA all processes and documentation are led by the country and derive inputs from discussions with stakeholders facilitated by the country focal point, with the assistance of IRENA and other development partners, for example, in Kiribati's case the WB, the Asian Development Bank (ADB), and SPC/GIZ. The resulting report is therefore a national one, developed and owned by the country. This sets the process and methodology of the RRA apart from other assessment processes led by international organisations. IRENA offers its support during the RRA, but it is the actions and insights that are developed through country-owned process that provide the key to rapid deployment of renewable energies.

The RRA facilitates a co-ordinated approach and the setting of priorities that can facilitate discussions with bilateral and multilateral co-operation agencies, financial institutions and the private sector regarding the implementation of actions and initiatives emerging out of the RRA. IRENA's backing of the RRA process offers countries access to a global network with the capacity to follow up on actions and facilitate an exchange of experiences. IRENA can also facilitate implementation of the follow-up actions, where necessary, after the specific request from the country or regional entity.

The key features of RRA include:

- Comprehensiveness: By reviewing the existing knowledge and studies within the country, the RRA ensures assessment of conditions for renewable energy deployment in a country is wide-ranging.

- Country-led process: Designed to be conducted by national governments, the RRA allows countries to obtain a comprehensive overview of the conditions for renewable energy from their national perspective. All the processes and documentation are led by the country and derive inputs from the discussions with stakeholders, as facilitated by the country focal point. The resultant report is a national one, developed and owned by the country.

- Process oriented: The RRA contains a process to build partnerships and gather key stakeholders to ensure consensus on the actions identified and their implementation.

- Facilitation of discussion and transparent consensus-building: The actions and background materials of the RRA are discussed openly and a wide range of viewpoints are reflected.

- Supporting stakeholder development: Through the RRA national governments initiate and take the lead in completing the assessment and the actions identified as a result of the process.

- Laying the foundation for future collaboration: A co-ordinated approach is used and there is setting of priorities that can generate discussions with funding agencies and the private sector regarding implementation of actions and initiatives emerging from the RRA.

OBJECTIVE

An overall objective of this country report is to highlight the significant results of the RRA that can help in formulating Kiribati's renewable energy development action plan, mobilising all resources necessary to carry out the actions identified and flagging the potential issues that need to be further addressed.

More specifically, the RRA aims to:

(a) Identify the critical and emerging issues associated with and arising from the development of Kiribati's energy sector in general and the utilisation of renewable energy resources in particular;

(b) Put forth a portfolio of articulated actionable initiatives that can capitalise on the opportunities revealed through the examination of Kiribati's energy sector and the extensive discussions with multiple stakeholders in terms of how to turn potential of resources into energy sources;

A photo of Kiribati (fishing boat)
Source: Herb Wade

(c) Outline the follow-up activities to ensure the actions identified are actionable in the near- and mid-term timeframe.

Lastly, the report serves to document the process of applying the RRA methodology to Kiribati. It includes reviewing the energy sector in relation to the development of renewable energy sources in the country, describing how the RRA workshop in Kiribati contributes to the development of an action plan to scale up the deployment of renewable energy sources in Kiribati, and articulating the actions identified into a structured portfolio. This not only ensures synergies, but more significantly facilitates harmonisation among the stakeholders involved to help deliver Kiribati's goals.

II. Energy and Renewable Energy

This section provides an overview of Kiribati's energy sector with a special focus on renewable energies. A historical perspective is included to highlight the renewable energy competence and knowledge that are already existent in Kiribati. It also indicates the stakeholders involved and the regulatory frame-works for renewables that have been put in place. The focus for financial investments is on how the donor community has provided support in using renewable energy sources in Kiribati. The last sub-section highlights the need to enhance human capacity to support the expansion of renewable energy applications.

THE REGIONAL CONTEXT

As with all Pacific Island Countries (PICs), with the exception of Papua New Guinea, Kiribati has no domestic fossil energy resource of any kind. Engagements with the other Pacific countries exists at two fronts:

1. Importation of energy fuels for power and transportation in Kiribati, which is carried out by the Kiribati Oil Company (KOIL) from suppliers in Fiji.

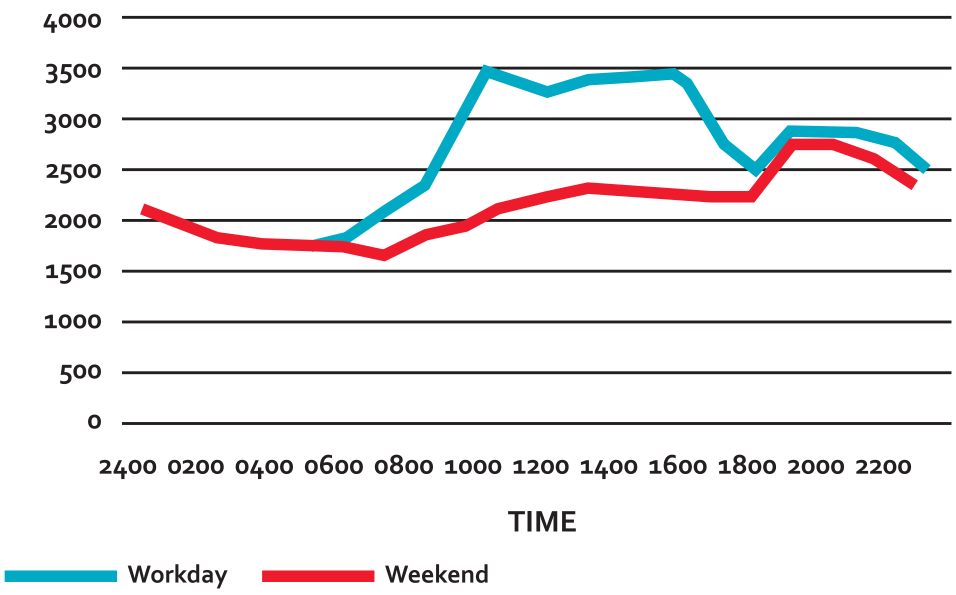
2. Technology sharing and co-operation through many regional platforms and programmes including the Pacific Power Association (PPA), the University of South Pacific (USP), the Secretariat of the Pacific Regional Environment Programme (SPREP), the Secretariat of the Pacific Community (SPC), the PEC, and others.

OVERVIEW OF THE ENERGY SECTOR

The energy profile for Tarawa and Kiritimati are very different from the outer islands. Electrical and petroleum energy use are dominant in Tarawa and Kiritimati, while in the outer islands most energy is supplied by biomass.

Supply of electric power is provided primarily by the Public Utilities Board (PUB) on Tarawa, though there are small grids on Kiritimati and at some boarding schools and IC facilities on other outer islands. The on-grid access to electricity is about 44% by the PUB plus another 3% by the multiple small grids on Kiritimati and other outer islands. Off-grid access is estimated at about 17% through the KSEC and private solar

Figure 2: Tarawa Load Curves (kW Load)



Source: PUB

home systems on outer islands, though about a third of those are currently not working. The Energy Planning Unit (EPU) within the MPWU reported that the PUB had 2 064 residential meters, 574 commercial meters and 290 government meters on its grid in 2011, plus there are about 150 public streetlights on Tarawa that are not metered. Electricity is also supplied through small grids on Kiritimati Island and in the vicinity of IC Offices on the outer islands but customer numbers are small.

As with many Pacific utilities, there are two load peaks during the work week: a daytime peak that corresponds with air conditioning loads for government offices and a smaller evening peak that corresponds with residential lighting and entertainment use.

Weekend load patterns show only the evening peak. This has implications for large scale solar use since the noontime load on the weekend is around 2.3 MW, while during the work week it is around 1.5 times higher at 3.4 MW. Thus any problems with integration of solar PV into the grid are most likely to occur on the weekends. This will need to be considered in the design of grid-connected solar installations, to reduce the likelihood of grid instability on Saturday, Sunday and holidays when the air conditioning load for government is not present. As seen in Table 1, Tarawa electricity demand in 2011 was about 6.6 GWh for government, 7 GWh for domestic and 3 GWh for commercial. Since there is no significant tourism or other industry, commercial uses are mostly for stores and offices. In recent years there has been little growth in demand.

As seen in Table 1, the 2011 sale of generated electricity on Tarawa was approximately 17.3 GWh, requiring a use of around 5.8 megalitres (ML) of automotive diesel oil (ADO). Notably, the electrical units gener-

Table 1: **Electricity Statistics 2005-2011** (MWh)

Year	Billed			Not Metered		Total MWh	Total Fuel Used at PUB [kl]
	Domestic	Commercial	Govt.	Water & Sewer[3]	PUB[4]		
2005	7 893.00	5 093.00	3 376.00	568.09	23.48	16 953.57	5 913.73
2006	6 864.00	4 500.00	4 458.00	568.09	3.13	16 393.21	6 235.66
2007	7 562.00	2 854.00	8 331.00	568.09	10.50	19 325.58	6 293.07
2008	7 197.00	3 073.00	7 335.00	568.09	8.52	18 181.61	5 881.87
2009	7 395.58	2 826.61	7 170.05	568.09	44.94	18 005.27	5 812.71
2010	7 111.00	3 086.00	7 029.00	568.09	2'0.32	17 814.41	5 744.97
2011	7 060.00	3 051.00	6 629.00	568.09	14.03	173 22.11	5 791.26

Source: PUB

ated on Tarawa increased to 21.8 GWh for 2011, as compared to 21.6 GWh in 2010, though the total billed GWh for these years indicates a significant electricity loss for 2011. Recent production figures for Kiritimati were not available but it is estimated that its electricity generation is a small fraction of that of Tarawa.

Although residential electricity use on Tarawa fell more than 11% from 7 893 MWh in 2005 to 7 060 MWh in 2011 and commercial usage fell 40% from 5 093 MWh in 2005 to 3 052 MWh in 2011, the usage for government experienced a significant surge over the years, rising to around 96% from 3 376 MWh in 2005 to 6 629 MWh in 2011. In recent years total demand has levelled off and there are no pressures other than population growth expected to increase electricity use.

For the outer islands, the per-capita energy use is low and is mostly in the form of biomass combustion for cooking and copra drying[5], where coconut husks, coconut shells, coconut fronds and mangrove wood serve as the traditional energy sources for Kiribati. In the outer islands, use of petroleum product is mainly in the form of kerosene used for lighting and petrol (gasoline) to operate some motorcycles, outboard powered boats and a truck and/or tractor owned by the IC for island transport use. Traditional sailing canoes are used extensively for subsistence fishing, thereby keeping petrol use low on the outer islands. By 2011, more than 2 100 rural households were powered by solar energy, which accounts for around 20% of the outer island households, though a significant number of those systems are not presently working[6] .

3 Water and sewerage is estimated to be the same every year, however it could less or more for some years.

4 PUB is for all PUB's premises' consumption except the Power house consumption which is around 4% to 5%.

5 Open solar drying is sometimes used but is much slower, less controllable and simply does not work when it is cloudy. Also there are more problems with mould since it takes longer time to dry copra. Enclosed solar dryers achieve better performance but they are expensive and require substantial maintenance which is difficult for users to arrange. All commercial copra producers use direct heat or steam heat for drying in Kiribati simply because it is the most cost effective and provides the best quality product.

6 KSEC /EPU

Table 2: **Kiribati Fuel Imports 2007-2011** (litres)

Fuel	2007	2008	2009	2010	2011
TARAWA FUEL IMPORTS					
Unleaded Petrol	5 230 500	5 131 471	5 258 870	5 364 063	5 856 928
Automotive diesel oil	12 625 887	12 890 915	12 109 923	12 225 730	11 155 939
Kerosene (Jet fuel)	2 793 527	2 727 099	2 538 534	3 664 506	3 290 651
TOTAL	**20 649 914**	**20 749 485**	**19 907 327**	**21 254 299**	**20 303 518**
KIRITIMATI FUEL IMPORT					
Unleaded Petrol	450 133	996 382	271 836	855 318	587 104
Automotive diesel oil	1 665 006	2 388 615	980 082	2 031 901	1 202 125
Kerosene (Jet fuel)	867 615	713 017	283 231	1 065 665	775 776
TOTAL	**2 982 754**	**4 098 014**	**1,535 149**	**3 952 884**	**2 565 005**

Source: KOIL

Electricity in rural areas comes from solar home systems except for the IC Offices and some housing immediately around the IC compounds, where a small generator typically is operated a few hours a day. Those generators serve a total of about 3% of Kiribati residences.

Due to the fact that Kiribati has no fossil fuels, the demand for petroleum products, mainly diesel, gasoline and kerosene, is met solely by fuel imports though CNO is produced locally and there is potential for it to replace a portion of petroleum imports. With the recent increase in energy prices at the international markets, Kiribati's annual spending on fuels is at the range of USD 8-9 million. This in turn has pushed electricity prices up to a level among the highest in the region, ranging from USD 0.42/kWh to USD 0.73/kWh, according to the MPWU.

Petroleum-based fuel is imported by the KOIL from suppliers in Fiji. Both Tarawa and Kiritimati Island have storage tanks that meet international standards for safety and construction. Fuel to the outer islands is shipped in 200 litre drums, which are typically stored in a fenced in compound at the KOIL agency facility on each atoll. Leaks are common and contamination by dirt and water also can be a problem.

LPG use is growing on Tarawa to replace kerosene for cooking. The government-owned corporation KOIL and Kirigas, a private company that is a subsidiary of Tarawa Motors, both import LPG. Until 2008, KOIL and Kirigas imports were both about the same, with KOIL importing 111 145 kg and Kirigas 104 036 kg in 2008, according to the records in the Kiribati Customs. However in 2009, KOIL imported 138 858 kg and Kirigas only 29 462 kg. Unfortunately 2010 and 2011 data are not available[7] .

Fuels used for the PUB and for aviation are

7 EPU

not subject to tax, so there would be no loss of tax revenue to government if PUB shifted to locally produced biofuel.

Kerosene is price controlled and is the same price on the outer islands as on Tarawa. According to 2010 census, about 34% of all Kiribati homes use kerosene for lighting.

RENEWABLE ENERGY SOURCES AND POTENTIALS

Kiribati is resource poor in general but does have good solar energy resource. However, thus far the share of solar in the energy balance accounts for no more than 1% of the total energy consumption, as it has been used almost exclusively for outer island lighting and basic electrification with little grid-based generation. This is soon to change with large grid-connected solar installations planned in co-operation with the WB and the PEC Fund. Biomass is by far the largest renewable energy use, with coconut husks, shells and fronds being the dominant energy source for cooking and copra drying in Kiribati due to its abundance[8]. Biomass is estimated to supply about 25% of the gross national energy use, according to Kiribati's 2009 National Energy Policy. Other renewable energy sources, such as wind and biofuel, remain negligible sources, though there is substantial development potential.

SOLAR ENERGY

Although the solar resource varies to some extent from north to south, in general Kiribati is endowed with an excellent solar resource. According to NASA surface meteorology and Solar Energy Database, the average daily solar radiation (horizontal) is about 6 kWh/m^2/day in Tarawa and 5.7 kWh/m^2/day in Kiritimati.

Due to Kiribati being close to the equator, seasonal variations in solar energy are not great, though there are seasonal cloud cover differences that have to be considered. Longer term variations also may exist due to the El Niño/El Niña Oscillation Cycle and the long term effects of climate change on cloudiness are yet to be determined.

Since the 1980s, the Kiribati government has had as its unwritten but effective policy that only renewable energy should be used for outer island electrification. For the past three decades, donors in particular the Japanese International Cooperation Agency (JICA) and the EU, have been providing SHS for households and larger solar installations for community buildings, schools and health centres on the outer islands. Half the population of around 10 000 could potentially have SHS electrification. Since 1984, Kiribati has installed over 2 200 SHS using donor funding. Some 98% of those serve the rural population, providing basic electrical services to around 20% of Kiribati's rural households including the northern part of the Tarawa, as shown in the photo, while the southern part of it is serviced by the grid.

SHS IN KIRIBATI

Solar PV for home lighting in the Kiribati outer islands was first introduced in the early 1980s by overseas workers, mostly seamen, who purchased the panels and controls overseas and brought them home to help out their rural families. In 1984, using United States Agency for International Development (USAID) funding, the

8 Due to higher population density in South Tarawa, coconut husks and shells have to be imported from North Tarawa for cooking. Thus people also use kerosene for cooking. Also the South Tarawa economy is cash oriented (mostly government employees) and people have cash to buy kerosene. Certainly there is no lack of husks and shells for cooking or drying on the outer islands.

KSEC was established as a non-government corporation mostly owned by an international non-governmental organisation Foundation for the Peoples of the South Pacific (FSP), to sell PV systems and appliances to individual households and provide solar PV installation and maintenance services when customers were willing to pay the cost of getting the technicians to the installation site. However, this business model based on private sale of systems did not survive long due largely to the poor quality of the installations carried out by the owners of the systems (who rarely took advantage of the installation services offered at cost by the KSEC) and the lack of post-sale maintenance, which resulted in about a 90% failure rate within a year or two of installation. This caused the outer island populations to lose confidence in solar and the sales from KSEC fell just as rapidly as they had increased. As a result the KSEC was essentially bankrupt by 1989.

Majority of the ownership was turned over to the government in 1986 and the rest of the FSP shares and shares held by the Bank of Kiribati were later turned over to government, so it is now classed as a government-owned corporation.

The business model of the KSEC was then changed from a sales company to today's solar utility whereby the KSEC owns the SHS and does all maintenance and repairs on the systems using well trained technician employees. The operations and maintenance (O and M) costs were then intended to be recovered through users paying a periodic fee paid by users, which was originally at AUD 9 per month per basic SHS installed. In 1992, with initial support for the hardware for 57 installations on North Tarawa coming from Japan, the KSEC was able to provide reliable and cost effective solar services to its rural users. The overall operation was a success as measured by a high percentage of fee collections, customer satisfaction and technical performance. In 1994, further funding support from the EU enabled the KSEC to not only electrify larger rural areas by adding Nonouti and Maiana islands to the utility coverage area, but the KSEC also became an exporter of technical goods by manufacturing controllers for Tonga, Fiji, Tuvalu and PNG, who were also participating in the EU project.

A maneaba solar PV system in North Tarawa
Source: Herb Wade

The success of the existing JICA and EU projects prompted funding of many solar project proposals by donors. Canadian aid provided funding for outer island health centre installations that included lighting and solar refrigeration. The UNDP and other donors funded a series of solar pumping projects, and solar installations were ordered by private institutions in rural areas, mostly schools and churches. These solar system sales, which in most cases included installation contracts as well,

Installing a solar panel in a Kiribati home
Source: Herb Wade

provided the additional funds necessary to maintain a positive cash flow for the KSEC in the 1990s, since the number of solar utility customers, about 325, remained below the break-even point for the KSEC. Also, the KSEC continued manufacturing their highly reliable controller for sale internationally, with orders coming from Tonga, Fiji and Bhutan.

A second round of EU funding starting in 1999 added over 1 700 solar installations and brought solar to all the islands of the Gilbert group. This jump from 325 installations covering three islands to over 2 000 installations covering 18 islands was very difficult for the KSEC to manage and there have been a number of problems and management issues as a result.

At the start of the 2000s another challenge to the KSEC that emerged was the result of monetary inflation over the years. This increased operational deficits, as the service fee of 9 AUD per SHS had remained unchanged since 1992. The KSEC Board and the Ministry of Finance agreed in 2008 to gradually increase the fee over a period of years in order to catch up with the inflation that had occurred since 1992, when the fee was initially set. However in 2009 the Kiribati Cabinet decided that the KSEC should continue to charge the same monthly fee of AUD 9 per month and the government would pay the unrecovered costs through an annual subsidy. Although the subsidy was initially paid as promised, the KSEC Board and KSEC management chose to allocate the subsidy elsewhere instead of the expected battery replacements. As a result there have been increasing problems with battery failures and non-payment of fees. After the first year no further subsidies were received and the KSEC is now facing serious financial issues. The current estimate is that over one-third of the outer island solar installations are no longer working to design specifications due to a need for battery replacement. This has had a cascading effect on the KSEC income, since people who had been paying the fee for years with the expectation of receiving proper maintenance of their systems have been without power due to battery failures for long periods. They now doubt the promise of maintenance in return for the fees paid.

As a result, those remaining households whose systems continue now often fail to pay their monthly fee since, as they too are under the assumption that they will not receive reliable services in exchange for fee payment. This has resulted not only in a reduction in fee collections due to non-operational systems but also a reduction in the percentage of receipts of payments for working systems, making the cash flow situation at the KSEC even worse.

As noted in the 2004 Kiribati national report from Pacific Islands Renewable Energy Project (PIREP) report, a number of lessons were learned through the KSEC rural electrification projects including:

- 100 Wp is the minimum acceptable panel capacity for SHS in most homes in rural Kiribati.
- Good quality batteries can provide continuous service for 10 years and more if reliable charge controllers and adequate panel capacity are included in the system design and batteries are not exposed to excessive heat.
- Rainwater can be used for battery water replacement if carefully collected and stored.
- The South Pacific Institute for Renewable Energy (SPIRE) Pacific controller design can be successfully manufactured in Kiribati and can provide substantially higher reliability and longer battery life than off-the-shelf commercial controllers.
- A majority of rural households in Kiribati can and will pay AUD 9-10 per month for basic lighting and radio services.
- The fee collection rate depends mainly on the confidence of users that they will receive the promised services they agreed to pay for.
- Field technicians need to be sufficiently mature to have the respect of the community and to be able to fully understand their responsibility for funds management.
- One field technician can successfully manage 100-120 household systems for maintenance and fee collection.
- Development of reliable energy service company operations increases the opportunity for the sale of PV systems and for the maintenance of private installations.
- Management of personnel is the most difficult part of solar utility company operations.
- Good quality accounting and records management are essential to successful energy service company operations.

SOLAR WATER HEATERS

There have been few solar water heaters installed in Kiribati and several have had technical failures due to mineral deposits in the solar collector tubes, a typical issue when using the "hard" water of the atolls (PIREP, 2004). The Chinese manufactured vacuum tube "heat pipe" type of water heaters have apparently worked well in Kiribati, though there are still only a few installed in Kiribati, as the demand for water heating is low.

GRID-CONNECTED SOLAR POWER

In recent years as the cost of imported fuels has dramatically increased while the costs of PV panels have significantly dropped, the economics of utility-scale solar PV system look attractive. A feasibility study on the potential for grid-connected solar PV on the South Tarawa grid system has been undertaken under the assistance of the WB. The study finds that 900 kWp (STC) and 800 kWp (AC) of solar PVs can be connected to the grid without the need for enhancements to the grid systems and operations provided the installations are appropriately sized, specified and located and there are controls to cut back on solar

Roof-top solar on ANZ, Kiritimati Island
Source: Bruce Clay

input on weekends and holidays to ensure grid stability can be maintained during those lower load periods. Kiribati, with the support of the WB, has agreed on four sites where an initial 516 kWp (STC) of solar PVs are to be installed with funding from AusAID through the Pacific Regional Infrastructure Facility and the Global Environment Facility. According to the WB, design and specifications for the installations have been completed and the project is ready for negotiation of agreements so implementation can commence. In addition, Kiribati is working with the PEC Fund to explore the feasibility to install additional solar PV capacity to take the total installed capacity to the technically feasible limit of 900 kWp of grid-connected solar PV systems.

On Kiritimati Island, there is already an 18 kWp grid-connected installation privately installed on the ANZ Bank building on Kiritimati Island, as shown here.

SOLAR PUMPING

There have been several solar pumping projects both for villages and for schools installed over the last 20 years. The initial UNDP project for village water supply installed positive displacement pumps, which mostly failed during the first few years of operation. Given the shallowness of Kiribati's wells and the coral dust in the water that is very hard on pumps, later projects have used mostly centrifugal pumps that have survived much longer. Unfortunately the villages and schools that received the earlier projects failed to perform proper maintenance and repairs on the pumps and almost none survived for the long term. In recent years most have been rehabilitated, with the water division of the Public Works Department (PWD) arranging maintenance.

OTHER SOLAR ENERGY APPLICATIONS

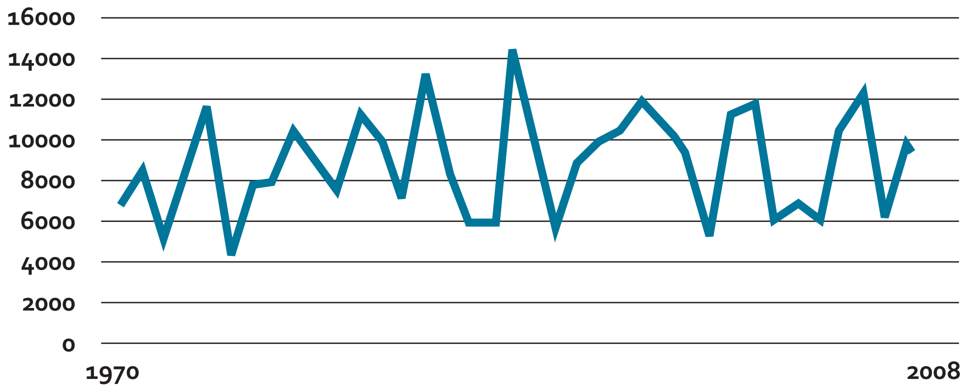
Another application of solar power is solar street lighting, which since 1998 has been used with success on South Tarawa along the 2 km of causeway between Betio and Bairiki. The fluorescent street lights are powered by an 80 Wp panel and a sealed battery that is placed underground to avoid being overheated by the sun. By keeping the battery cool, the batteries have lasted up to 10 years.

In addition, several solar lighting and solar refrigeration projects were purchased and installed at private schools, churches and other private facilities. Telecommunications on outer islands are also all solar powered.

BIO-ENERGY

As in many of the Pacific Islands, coconut palms are very common and cover about 70-80% of Kiribati's land area. The Gilbert Group of islands has about 190 km^2 of land under coconut tree growth, while the Line and Phoenix groups have around 330 km^2 (mostly Kiritimati Island). This represents around 6.1 million trees. Of these trees around 2.8 million are considered senile

Figure 3: **Copra Production in Kiribati**
(Metric Tonnes, 1970-2008)



Source: Kiribati National Statistics Office

with low production and are due for replacement if the demand for copra increases. Copra production is the key agro-forestry activity in the outer islands, making it the main source of income for the rural population through exportation of copra to the oil mill on Tarawa. To aid the outer islands' economy and to reduce emigration to the already overcrowded capital island of Tarawa, the government has a copra price stabilisation programme that in effect has provided a subsidy to copra producers with a current fixed price of AUD 600 per tonne.

The coconut husks and shells that are the waste from copra production have traditionally been the primary cooking and crop drying fuels for the islands, even in South Tarawa. As shown in Figure 2, copra production has fluctuated significantly from 1970-2008. This was partly climate driven but also due to market factors.

Although the copra production on the outer islands has provided more than enough biomass for cooking, the high population density of Tarawa has made biomass fuel scarce and expensive, causing most households to add kerosene or liquefied petroleum gas (LPG) to their list of cooking fuels.

BIOFUEL

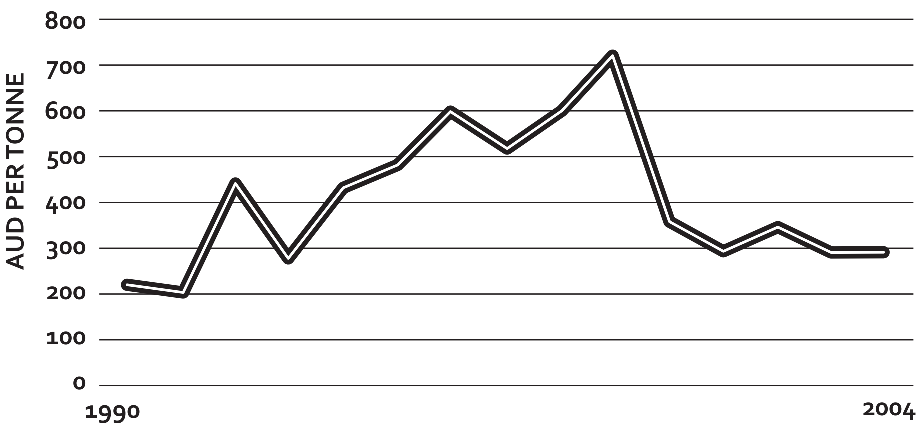
In May 2001, the Kiribati Copra Mill Company Ltd (KCMCL) was founded as a wholly-owned corporation by the government of Kiribati. It was designed to produce mainly CNO for export, which earns a premium compared to copra in the international marketplace, as well as for local consumption. The mill can crush about 35 tonnes/day of copra with a maximum oil extraction yield of about 15-20 tonnes/day, which also produces around 10 tonnes of dry copra cake per shift. Due to the limited processing capacity, only about 20% of produced copra is able to be consumed locally to produce CNO and CNO products (Tarakia 2009). The remaining copra must still be exported to overseas markets. In 2010 the mill crushed 4 062 tonnes and produced 2 293 tonnes of oil. In 2011 it crushed 7 980 tonnes and produced 4 325 tonnes of oil at a price of AUD 1 080 per tonne Cost Insurance Freight (EPU 2012).

In recent years, the international market price for CNO has generally been low while diesel prices have moved upwards. From a purely economic perspective, CNO-based biofuel looks promising as a substitute for petroleum-based diesel that would otherwise have to be imported. The graph in Figure 4 shows how the international market price fluctuated relative to the fixed price set by government at AUD 600 per tonne.

The KCMCL understands the possibilities of using its produced CNO as biofuel and has been refining coconut oil for mixing with diesel fuel or kerosene to make a form of biofuel. The refining process includes some reduction in fatty acid content and 5 micron filtering. In 2006 the plant boiler successfully used diesel for start-up and biofuel for its operation. Tests of various blends of CNO and diesel fuel or kerosene have been carried out and it was found that at above 20% CNO mixed with diesel fuel the boiler was hard to fire up but with kerosene trials up to 40% kerosene and 60% CNO was satisfactory. Tests also have been carried out on the plant backup generator and vehicles. Tests were stopped when engine problems occurred, mostly in the form of fuel filter clogs and carbon build up in the engine cylinders (Cloin 2007).

A South Pacific Applied Geoscience Commission (SOPAC) study published in 2006 estimated that the annual production of CNO in Kiribati could be sustained at 3-4 million litres per year and could be used for biofuel without impacting traditional uses, including pig feed and human consumption. If the coconut resource is rehabilitated in order to increase the production of copra to meet an increased demand for CNO for biofuel, a major replanting programme will be necessary to replace some

Figure 4: **Copra Export Prices**[9]
(1990-2004)



Source: The Kiribati Copra Cooperative Society (KCCS)

9. Exchange rates for the AUD; 1993 1 USD = 1.48 AUD; '94=1.35;'95=1.40;'96=1.25;'97=1.31;'98=1.62;'99=1.55; 2000=1.74;'01=1.97;'02=1.76;'03=1.53;'04=1.40;'05=1.32;'06=1.32

of the 2.8 million senile coconut trees. At present, Kiribati's Ministry of Agriculture has prepared a pilot plan to replant and replace senile coconut trees. This plan will be implemented once funding is available. The plan is to make high quality seedlings available at a subsidized price and arrange for either the purchase or disposal of the tree that is cut. In a scenario where the demand for coconuts increases, farmers would want to replace low production trees in order to increase productivity from their acreage so no special incentives would be needed. Such replanting projects were used in the 70's when coconuts were a major agricultural product and high productivity hybrids (mostly from the Philippines) replaced the lower productivity species that grow naturally in the islands.

As a result of replanting, a significant amount of biomass would be made available in the form of the senile trees that are cut down, though it may be more economically appropriate to use the coconut wood as an export product or for local use for construction, furniture and decorative wood products than as an energy source.

There is also modest potential for biogas production if community pigs were kept penned in small areas and their manure collected for biogas generation. However, there are no commercial piggeries or cattle farms in Kiribati and the traditional approach to pig farming is having free ranging, family-owned pigs. Additionally, the trials of biogas throughout the Pacific have not been well accepted except in a few large -scale piggeries and cattle farms, where the value of the biogas plants is seen to be as much for the processing of waste as for the production of gas. Since the potential for saving fuel is small and the social and financial investment needed to make it practical appears high, it is unlikely that agriculture-based biogas will be a significant resource in the near-term. However, should Tarawa construct a sewage treatment facility, as has been proposed, then providing for biogas production from sewage (and burning of said gas for electricity production) to offset the energy use of the plant could be appropriate.

WIND ENERGY

Wind power has been used to pump water in the past but has been replaced by solar pumping in the Pacific, as it is considered more reliable. It is clear that wind energy resource is seasonal but in general the wind energy resource is poorly understood and good quality resource surveys need to be carried out before there is any consideration of wind power generation investment. Wind installations are particularly difficult for atoll islands due to their lack of significant elevation and the dominance of tall coconut trees over most land areas. Installation of wind machines in shallow lagoons or on the reef well away from trees may be required if wind power is to be practical for most of Kiribati. However, this could have significant environmental impacts for the lagoon or reef. Fortunately, cyclones are rarely a problem in Kiribati due to its proximity to the equator.

A wind energy assessment has been carried out on Kiritimati Island, since it has a much larger and more open land area than the other islands and can support a small wind farm. The assessment found that wind energy can be economical for power generation in Kiritimati and wind power will therefore be considered as a potential energy source when a power development plan for Kiritimati is prepared.

OCEAN ENERGY, A RESOURCE FOR THE FUTURE?

The great hope for all the Pacific Islands, particularly the resource poor atolls such as the islands of Kiribati, is that the vast energy in the surrounding ocean can be tapped for electricity generation. Thus far, there has been no commercially acceptable means of converting wave, current, tidal or ocean thermal energy for use in Kiribati. Trials of wave energy conversion in Tonga and of OTEC around the world have been proposed and should be monitored by Kiribati. If the trials of any of these technologies show promise for Kiribati, a resource survey for that technology should be carried out in preparation for a possible future installation.

KEY ENERGY STAKEHOLDERS AND LEGAL STRUCTURE OF THE ENERGY SECTOR

The MPWU has primary responsibility for the planning, management and co-ordination of the energy sector. Other entities with energy sector responsibilities are:

- The EPU within the MPWU co-ordinates the implementation of energy policies and provides advice and assistance on all energy related matters and activities.
- The PUB is a government-owned body responsible for provision of power, water supply and sewage services for South Tarawa.
- The KSEC is a government-owned company responsible for the provision of electrical services for rural areas through the operation and maintenance of solar PV systems. It currently manages around 224 kWp of solar for outer island residences, 47.6 kWp of solar for community buildings, 7.5 kWp for streetlights and 6.4 kWp for communications (National Energy Policy, 2009). In the past it has also been contracted for the maintenance of solar pumps for the Public Works Department, health centre solar installations, school solar systems for the Ministry of Education and solar installations for schools of various church groups.
- The Public Works Department (PWD) maintains a number of solar pumps throughout Kiribati that are used at schools, villages and IC facilities.
- The KOIL is a government-owned company involved in the import and distribution of petroleum products throughout Kiribati.
- The MLPID is responsible for all government services, including electricity supply, on Kiritimati Island and the populated Line and Phoenix islands.

LEGAL STRUCTURE OF THE ENERGY SECTOR

The Public Utilities Ordinance (CAP 83 of 1977 revised 1998 and 2010) provides the legislative basis for the formation of the PUB. It also provides for the MPWU to declare electricity supply and/or water supply areas as exclusive to the PUB for the provision of services. The ordinance was amended to provide more autonomy to the PUB and it is currently acting as a parastatal body with its own terms of service and tariff management.

- Prices Ordinance (Cap 1975 and revised in 1981) - Includes price controls for petrol and kerosene. Diesel is not under price control.

- Petroleum Act (Cap 69) - This act regulates safety, storage, rationing, and customs inspections.

- Environment Act (Act 9 of 1999 amended in 2007) - Provides for the protection, improvement and conservation of the Kiribati environment, Supplemented by Environmental Regulations 2001.

The three key local suppliers of energy services are all state-owned entities. The KOIL imports and distributes petroleum products (except for some private importing and distribution of LPG), the KSEC is responsible for more rural electrification and the PUB provides electricity, water and sewage services on most of Tarawa. Due to the total dependence of the modern segment of the Kiribati economy on imported fuels, the increasing cost of those fuels has created serious economic problems for the Kiribati government.

ENERGY POLICY AND REGULATORY FRAMEWORK

ENERGY POLICY OF 2009

The National Energy Policy was established in association with the Kiribati Development Plan 2008-2011 and has as its primary goals human resource development in the energy sector, development of livelihoods, energy security and energy access. The guiding principles are sustainability, gender equity, environmental compatibility, stakeholder participation, good governance and cultural/traditional compatibility.

With regards to renewable energy the policies include:

- Promoting sustainable renewable energy access;

- Ensuring that the limited biomass resources are used in an economically, environmentally and culturally sustainable manner;

- Strengthening collaboration with development partners for the advancement of renewable energy programmes;

- Promoting and encouraging the use of appropriate renewable energy technologies;

- Expediting the replication of successful solar programmes; and

- Introducing appropriate incentive packages including taxes, duties and tariffs to encourage the use of renewable energy technologies.

The policy requires the MPWU to establish a regulatory framework for the energy sector, facilitate co-ordination for the implementation of climate change mitigation activities in the utilisation of renewable energy resources and ensure the co-ordination of energy requirements for any major infrastructure development.

REGULATION

The PUB, KSEC and KOIL all operate under a Board of Directors appointed by the Kiribati government and are essentially self-regulating, though the MPWU has oversight responsibility. All are required to submit auditable financial statements annually and the government carries out an audit. Although in theory tariffs for the PUB and

KSEC are set by their respective boards, higher levels of government have in the past overruled those board decisions and set tariffs directly. Prices for petroleum products from the KOIL (except for diesel fuel) are regulated under the Prices Ordinance.

FINANCING AND INVESTMENT

The government of Kiribati plays a key role in providing financial resources to the energy sector as the PUB is a state-owned enterprise. Almost 25% of the AUD 90 million (approximately USD 94 million) national import expenditure goes to purchasing fuels for power generation and transportation. Most of the capital investment in the energy sector comes from the donor community, including the EU, the World Bank, JICA and the PEC Fund among others.

Private sector investments are extremely limited. Investment in the energy sector is low in Kiribati, as it is considered to be unattractive and few enterprises have any activity relating to energy development.

HUMAN CAPACITY

Human capacity enhancement is needed within the PUB, KSEC, KCMCL and KOIL with regards to business management, record keeping and business planning. Kiribati's skilled and well-trained engineers often find themselves better positions outside of the country, and migrate to another country. This leaves those who stay in Kiribati with the need to upgrade their skill sets.

There is lack of education and training in renewable energy systems. For the O and M and management of the various types of solar installations planned for Kiribati, particularly for the O and M of the grid connected solar PV systems, capacity building for the responsible technical staff needs to be provided. As noted elsewhere, the Kiribati Institute of Technology (KIT) and the University of the South Pacific local campus can be developed into local training facilities to support the renewable energy technologies used in Kiribati.

CNO biofuel development will require capacity building for quality control, testing and processing of CNO for use as biofuel is needed at the KCMCL and capacity building for CNO biofuel testing is needed for the PUB. The technical issues experienced in using CNO biofuels in the past were much associated with a lack of information about the specifications required of the product and the type of equipment needed for its refining and quality control.

Realistic summary information regarding the use, management, cost and capabilities of renewable energies being developed for use in Kiribati needs to be provided to government decision makers on a regular basis.

III. Development of the Renewable Energy Market

Opportunities to develop the renewables sector in Kiribati are discussed in this section. As the segmentation of the market is largely subject to what resources are available and useable and by way of what technologies they can be converted into energy sources to provide energy services for Kiribati, this section is divided into different sub-sections focusing on different resources and conversion technologies, known here as service-resource pairs. In each sub-section, the status of each particular sub-sector is reviewed, followed by the issues that need to be addressed and then concluded with a list of actions that were recommended by the RRA.

SERVICE-RESOURCE I: GRID-CONNECTED SOLAR PVS

STATUS OF THE SECTOR

In a strict sense, there is only one power grid available in Kiribati, which is the South Tarawa power grid, serving nearly half of the national population. It is owned and operated by the PUB with a total power generation capacity of about 5.45 MW and is entirely fuelled by imported diesel. At present, there are no on-grid solar PV systems in South Tarawa.

Kiritimati has several hybrid powered micro-grids, which include one 18 kWp grid-connected solar installation, to provide electricity to individual villages. The cost of solar generation is now lower than the cost of operating these small generators and conversion of the small Kiritimati grids to solar power with diesel backup is a reasonable consideration. The village of Poland is already confirmed for EU funding to add solar to the existing grid. The villages of Tabwakea, Tennessee and Banana may be further candidates for solar conversion. Also solar power for the Spivey Secondary College and the San Francis Secondary College appear possible. The relatively large grid serving London has a 200 kWp evening peak and includes the 18 kWp of rooftop grid connected solar. It could probably accept more than an additional 20 kWp of PV installations without stability problems following the completion of the recently announced power consolidation project that will connect the existing small grids from London to Tabwakea.

However, for South Tarawa, to address the challenges stemming from over-dependence on imported fuels, the government of Kiribati has over the past years been stepping up efforts to investigate options to integrate utility-scale renewable electricity generation into the South Tarawa grid. This was motivated by two factors: the cost of imported fuels dramatically increasing over the past years and the cost of PV panels significantly decreasing. The combined effect contributes to the improved economics of utility-scale solar PV systems. In addition, fuel import reduction could also enhance energy security by reducing the impact of diesel supply disruptions caused by political, climatic and other issues.

ISSUES

At present, there is no grid-connected solar PV installation in the grid of South Tarawa. But the on-going solar initiatives with the support from the WB and the PEC Fund will put about 900 kWp of solar PV generation capacity into the grid – a level considered safe[10] according to the WB-funded feasibility study. However, one key issue affecting grid stability is the much lower daytime load on the weekends, when government air conditioning is not operating. The noontime load during the week is around 3.5 MW (see Figure 2) and 900 kWp represents 26% of that load. On the weekends the noontime load is around 2.4 MW. Thus 900 kWp represents over 37% of the load, an amount considered by many experts to put the associated grid at risk for stability problems from the rapid variations of output from the solar power generation systems. This indicates that under special conditions some solar PV throttling may be required, but not without an economic trade-off. The proposed modular design has to provide a solution as to how best to manage the "throttling back" and also consider to what extent this technique can be combined with a sophisticated solution to maintain the grid stability.

- Future grid stability is a major concern of the PUB. The WB's feasibility study indicates the grid's ability to absorb 900 kWp variable energy sources. The PUB, the governmental body responsible for power system reliability, is however concerned about grid stability issues in a scenario where capacity goes above 900kWp with additional grid-connected solar PV installations – as the 900kWp is close to the limit that the grid can take if no measure to enhance the grid stability is taken[11].

Since 900 kWp is considered the technical limit, additional solar will require some sort of stabilising storage and/or control systems to prevent de-stabilising vitiations from occurring, once the 900 kWp of solar has been installed through funding from the WB and the PEC Fund. In this situation, what additional grid-connected project

10 If each location of the installations does not exceed 300kWp and stay 2-3 kilometres apart.

11 This is because in the current circumstance the problem is only going to be manifested on the weekends but if another sizeable amount of kWp of solar is added then "throttling back" probably becomes a daily operation and for every kW added the economic benefits would be less and less and the decision as to whether or not to "throttle back" becomes more and more difficult.

concepts make sense for Kiribati, if any? Since additional scale grid-connected solar appears necessary to meet the goals set for reducing dependency on fossil fuels, should Kiribati seek donor funding for large installations on the ground or should it continue to focus on roof top solar? Should Kiribati seek outside investors to build and operate solar arrays and sell power to the PUB? Should the PUB seek many small grid connected solar installations that are easy to maintain and can be operated by the PUB itself, as has been considered in the past? These questions need to be considered early in the development of grid-connected solar in Kiribati and included in the action plan that is prepared to attain the national goals for renewable energy integration.

PUB management and technical staff needs to be supported in their preparations for such problems through the use of grid modelling software to determine at what point energy storage and solar output variation controls should be introduced into the grid infrastructure so that additional solar installations include design feature so that they do not introduce stability problems for the grid. So, they can be familiar with different approaches to addressing the grid stability issues when the problems are still manageable.

- The grid stability issue can be technically addressed but the greater long term challenges lie in how to bring all the key stakeholders together to discuss the stability issue and address it with a joint effort. Non-technical issues include: (a) how to effectively co-ordinate multiple donors who will be proposing grid-connected solar in terms of sharing the responsibility for grid-stability issues and creating synergies[12]; and (b) what legislative and/ or regulatory instruments such as standards both for Kiribati conditions and inter-changeability and acceptance or avoidance of private grid-connected solar/wind installations should be put in place relative to future solar based installations.

- There are no standards, laws or regulations for private generation using renewable energy that feeds into the grid. If the private sector is to be involved in on-grid renewable energy development, net-metering is important as are standardised arrangements for power purchase agreements and independent power producers.

- What renewable energy options should be used for Kiritimati and how should they be applied? Should the individual Kiritimati village grids be converted to solar? Should they be interconnected to create an island grid? From a renewable energy point of view, this is important since the manner that wind and solar can be integrated will be very dependent on whether they remain separate grids or are interconnected.

Although off-grid small-scale solar PV systems have been in use in Kiribati since the 1970s and are well understood by the KSEC, there is a lack of knowledge and experience in large-scale on-grid solar PV applications. If a rapid increase in the generation capacity of grid-connected solar PV systems occurs, a number of challenges to the PUB would emerge and have to be addressed in a timely and systematic manner. Since the emerging

12 A Solar Steering Committee currently coordinates the two pipeline projects and the WB will provide a solar engineer to supervise installations, a three-year O and M programme and a three-year capacity building programme for PUB and KIT and will also include KSEC to broaden the skills base.

issues on grid integration stem both from the technical aspect and the current institutional, capacity and legislative settings, a systematic perspective and approach is needed to address them.

RECOMMENDED ACTIONS

- Initiatives to maintain grid stability - In the RRA workshop discussions on this issue, the trade-offs between using solar to offset imported fuel consumption and weakening the grid stability due to the variable outputs of solar PV generation were discussed by the on-grid solar discussion group. It was agreed that some specific measures would have to be taken to mitigate the negative impacts of high levels of penetration by solar PVs systems on grid stability, especially since Kiribati will need to seek additional grid-connected solar PV generation capacity in the future if the renewable energy goals are to be met.

  This issue has three dimensions: (1) technology; (2) capacity building for operators and O&M technicians; and (3) regulatory and technical standards. Each has to be addressed individually in order for the issue to be effectively addressed as a whole. Additionally, effective donor co-ordination will have an important role to play when grid-connected systems proposed by donors are to be installed in the future.

  There are a variety of technical options available on the market. A number of recommended technical solutions were put forth, including adding energy storage to smooth out the solar input, computer management of solar inputs that slows down the rate of change of power from the solar or drops out solar input when changing too fast or too much, 'smart' grid technology that automatically adjusts loads to match solar input variations and other high-tech options using advanced control technology. In addition to the proposed technical solutions, the group also put forth that there is a need for capacity building including training the system operators.

- **Net-metering -** Developing net-metering regulations or legislation has gathered interest but it was agreed that net-metering would be useful only if it is determined that the grid can allow the integration of a number of small dispersed grid-connected PV installations after the completion of the 900 kWp donor-funded systems. The PUB would be unlikely to consider the net-metering scheme until the issues of potential grid stability following the installation of the 900kWp from WB and PEC fund are effectively addressed.

- **Capacity building -** Developing capacity of the PUB to monitor the grid status and maintain the stability of the grid was viewed as an important measure to enhance grid reliability. There have been a number of capacity building programmes funded by different donors in the region but few have addressed these issues. Such programmes need to be developed and provided by donors through existing training institutions such as the KIT and the University of the South Pacific (USP), with the support and advice of the Pacific Power Association (PPA), the Secretariat of the Pacific Community (SPC) and the Sustainable Energy Industries Association of the Pacific Islands (SEIAPI). The WB project includes a solar engineer to supervise and commission installations, a 3- year O and M programme and a 3-year capacity building programme for PUB and KIT and will include KSEC to broaden their skills base. Capacity building for the PUB is also planned within the PEC Fund project. For the long term, maintaining the required capacity at the PUB and adjusting it to fit increased inputs of renewable ene-rgy on the grid needs to be considered in any action plan that is prepared.

- **Developing standards and regulations for grid-connected solar systems -** Standards and regulations are needed to ensure the technical quality of the renewable energy projects and their appropriateness for the island environment. They are also important to make easier the maintenance, spare parts management and the training of technicians and minimise costs. Standards and regulations are also needed to safely integrate renewable energy systems into the grid. The discussion group noted the priority of safety of the public and maintenance technicians. Standards for system designs and components are critical for reliable and safe operation of the renewable energy systems. In addition, setting technical standards and regulations will help create guidelines for private sector participation, which may be needed if the fuel import reduction goals are to be met. In particular if the private sector is to take part in renewables, standards for designs and components makes it much easier to attain competency, since the scope of training required is limited to the technology covered by the standards.

- **Donor co-ordination -** It is vitally important that the WB and the PEC Fund co-ordinate their designs and installations. Discussions between those two funding sources and the government of Kiribati are underway. For the long-term, as more renewables are proposed for integration into the grid, which ones are allowed to be connected to the grid and how the projects should be implemented must be addressed to prevent grid stability issues. It was proposed by the RRA that IRENA could continue to play a co-ordination role to ensure that there is effective communication among the designers and implementers of donor projects and the PUB so that issues of grid stability will be addressed cooperatively and completely.

SERVICE-RESOURCE II: CNO BIOFUELS FOR PUB POWER GENERATION

This sub-section, together with sub-sections "Service-Resource IV and Service-Resource V", is focused on CNO biofuels in Kiribati and how they can contri-bute to the reduction of imported fossil fuels. The discussion out-comes in these three sub-sections were based on the group discus-sions in the two-day RRA work-shop and an extended discussion that was organised by the EPU for a smaller group on October 5th 2012 at the PUB.

STATUS OF THE SECTOR

Currently the PUB uses around 5.5 million litres of diesel fuel each year in engines that were provided through Japanese aid less than 10 years ago. Of the renewable energy sources available to Kiribati, CNO used for biofuel appears to be the lowest cost option for high capacity renewable energy-based power generation. Roughly 70% of Kiribati's land area is covered by a coconut tree canopy of an estimated 6.1 million trees. Production from that resource could be in excess of 3.5 million litres of CNO per year. On the other hand, the copra sector is highly subsidised and hence poses a huge financial burden on the government of Kiribati. Kiribati has examined several options to utilise CNO as a substitute for diesel fuel. For example, the KCMC attempted to use CNO in their production boilers at a blending ratio of 60% CNO with 40% kerosene (Cloin 2007). Through that experiment it was learnt that CNO must be treated and filtered to upgrade its fuel quality while moisture must also be removed. Additionally, a blend of CNO with conventional fuel was trialled in the mill generator and company vehicles. Today there is little doubt that diesel-powered generators can run safely on blended CNO if the challenges posed by CNO use are well understood and effectively managed.

Current Use:
Cummins Genset 400 KVA
10-20% CNO in Diesel Fuel
Savai EPC Power Station,
Samoa, 2005
Source: Gilles Vaitilingom

To date, there have been few trials of CNO for grid power generation in Kiribati but regionally there have been trials with a blend of CNO and diesel fuel in the large engines used for power generation in Vanuatu, Samoa and Fiji. UNELCO in Vanuatu is currently using fuel containing 30% (by volume) CNO and has reported no significant problems. On Savai'i, in Samoa, up to 20% CNO was used with no significant problems but due to supply and oil quality problems, Samoa is no longer doing trials of CNO with diesel. The Fijian government has established a standard that allows 5% CNO blend for general sale as biofuel, though the Fiji Electricity Authority is not currently using or doing trials of biofuel for power generation.

ISSUES

- Engine risk is a big concern in Kiribati. Since the PUB engines are not specifically designed to be compatible with CNO, the Japanese manufacturer will not support the use of even a blend of diesel and CNO. Therefore either the PUB accepts the risk of losing manufacturer warranties and support or installs an engine that is designed for coconut oil use.

- The price of CNO is currently set by the international market. So long as the PUB fuel purchase prices are equal or higher than the export value of CNO and/or copra, the delivery of the mill product for power generation is reasonably assured. However, should the export price of CNO and/or copra exceed the price that the PUB finds acceptable, there will be strong economic pressure to sell the CNO or copra for export and have the PUB revert to imported diesel fuel.

- Feedstock supply depends on mills receiving sufficient good quality copra to make oil that is suitable for use as a biofuel. For mills to have a secure supply of copra, shipping from the outer islands must be reliable and frequent, the productivity of the trees must be maintained and the price paid for the copra must be acceptable to the copra cutters. Currently shipping is irregular and the quality of received copra has suffered as a result. The price paid for copra in Kiribati is currently regulated and under the control of government, so the main factor is the oil or copra export market.

- The decline for copra demand over the past several decades has allowed many of the trees to become senile, with low productivity. An estimated 46% of existing trees have entered the senile phase of their life cycle. A greatly increased demand for oil to supply the PUB fuel will require the cutting and proper disposal of the old trees and replanting with trees specifically bred for high oil production. Currently the husks and shells left over from copra production are used for cooking fuel and other traditional purposes. If copra production is dramatically increased, a large surplus of husks and shells will be produced.

- A major issue with the use of CNO for fuel has been maintaining proper oil quality. Many of the problems, such as fuel filter clogging, can be avoided through the establishment of quality standards and testing procedures combined with better quality control of the oil intended as diesel replacement. This is related both to the quality of the copra delivered to the mill and to the operation of the mill itself, so a solution must include suppliers as well as millers.

RECOMMENDED ACTIONS

- **Prepare a CNO implementation plan -** Develop an implementation plan where CNO replaces diesel fuel that considers: (1) rehabilitation of coconut stands; (2) how to best utilise senile trees that have been cut down to make way for new planting; (3) how to best use husk and shell waste from large scale copra production; (4) whether to continue with centralised milling on Tarawa, use smaller scale milling on some or all outer islands or a combination of both; (5) how best to process the oil to meet CNO biofuel standards; and (6) how to regulate prices to avoid impact of international market price fluctuations.

- **Include a CNO-capable base load engine at the PUB -** An additional engine is being considered for the PUB to provide more flexibility and power reliability. This will be supported with the preparation of a project to purchase a dual fuel (CNO and diesel fuel) engine when the PUB purchases a new engine.

- **Establish a testing facility for CNO for fuel use -** Develop a complete, independent biofuel testing facility that can assure the PUB that delivered biofuel meets the standards that have been set for CNO to be used as a diesel fuel replacement.

- Establish small mobile mills to avoid shipping problems - Development of a mobile mill for the preparation of adequate quality CNO for biofuel use can prove helpful. This will contribute to developing CNO production for power generation on Kiritimati, as it currently has no mill and shipping CNO from Tarawa is expensive. Should the mobile mill be successful, it may be duplicated on the outer islands, especially those that have poor access to shipping.

SERVICE-RESOURCE III: OFF-GRID SOLAR PVS

STATUS OF THE SECTOR

The current estimate is that over one-third of the approximately 2 200 outer island solar installations, mostly SHS, are no longer working due to a need for battery replacement. This has had a cascading effect on KSEC income, as even previously compliant customers who have paid their fees for years in expectation of receiving proper maintenance of their systems have begun to stop payment, as they had not received the maintenance they had paid for.

As a further result there has been a reduction in fee collections due to many non-operational systems and the percentage of receipts of payments for working systems has fallen to new lows, further worsening the KSEC cash flow situation. A detailed plan for rehabilitation of the off-grid solar installations was prepared by the KSEC in conjunction with the Kiribati government, following which the government has promised to resume subsidy payments soon.

Other off-grid electricity generation includes small fossil fuelled generators at IC offices and facilities (typically one on each island) and small diesel generators at some boarding schools and health facilities. These generators typically run less than 24 hours a day.

ISSUES

- How to best address the rehabilitation of the outer island solar installations and how can the KSEC regain the confidence of its outer island solar customers and its cash flow?
- Should the small IC grids be converted to solar mini-grids or modified to run on CNO? Who should own, operate, maintain and manage them? To date these small grids have been installed *ad hoc* and are quite inefficient. It is important to establish a proper design, operation and management process so that they not only provide and deliver better quality power in an efficient manner but also meet safety and power standards.
- What off-grid project concepts make sense for Kiribati at this time? There is a known demand for electricity in rural areas. How should Kiribati fill that demand for residences? For businesses? For schools? For health centres?

RECOMMENDED ACTIONS

- **Rural Electrification Implementation Plan -** Fund a rural electrification implementation plan that includes the rehabilitation and expansion of solar for rural households and maneabas. The plan should be based on a carefully prepared survey of rural energy needs, willingness and ability for residents to pay for the services to meet those stated needs. A range of technically feasible solutions such as micro/mini-grid configurations, pre-paid metering devices and feasible management and operational models should be also carefully examined against the local contexts of Kiribati. In this way, it would ensure the proposed technical systems in the implementation plan could be well adapted into the varied localities within Kiribati and thus be operated in a sustainable fashion, both technically and economically.

- Combine solar maintenance under one agency - Determine the renewable energy maintenance needs of the various organisations providing outer island energy services for education, health, communications, power and water supplies. Also determine if it is a good use of resources to establish separate technical maintenance crews within each organisation, or given the shared nature of maintenance activities, should a specialist organisation, such as the KSEC or a new private company, be established to contract for all maintenance.

SERVICE-RESOURCE IV: OFF-GRID CNO-BASED BIOFUELS FOR POWER GENERATION

STATUS OF THE SECTOR

The sector has two segments: (1) the use of CNO for primary power generation or as back up for small-grid solar generation on Kiritimati; and (2) the possible use of CNO as fuel for outer island diesel mini-grids, supplying power to IC compounds, schools and other public facilities on rural islands. Currently most of ICs have a small generator that is operated a few hours a day for powering the IC facilities, which may include guest houses for visitors, the IC office, an associated school or health centre, workshops, storage buildings and the homes of IC employees,

ISSUES

- While simply converting existing diesel generators to CNO is the cheapest investment option, in the long run CNO is likely to be more expensive for outer island generation, compared to solar. That is partly due to the fact that fuel grade CNO is expected to be comparable in price to diesel fuel and currently outer island diesel imports are more costly per kWh generated than solar with batteries. The cost of solar generation is largely the result of high initial investment with moderate operational costs while for diesel generation the greatest cost input is the actual fuel, since the initial investment cost for equipment is modest. Since donor funding can probably be accessed for the off-grid solar investment, the cost to Kiribati for the solar electricity will be much lower than for diesel-generated electricity, since that fuel source will not be provided by donors.
- For solar energy to become the main power source for Kiribati, solar installations must be ‘oversized’ to be able to provide extra energy during the extended periods of cloudy weather, or they must have a backup power source such as a small diesel engine. Should CNO be the fuel of choice for back up generation?

RECOMMENDED ACTIONS

The following two recommended actions are proposed separately based on the reasons: (a) the Kiritimati grids are much larger and more complex than those serving the IC that generally are no more than a portable generator and; (b) there will be different agencies implementing the two different projects and they have different needs and expectations.

- **Solar versus CNO for the outer island mini-grids -** Fund a feasibility study that determines the economics and environmental effects of solar generation at the various sizes needed for ICs, schools, water pumps and health centres. Assume in one case that the solar power installation is oversized so there is no need for back up generation; and in a second case assume the solar power system produces 90% or more of the needed energy while CNO-powered diesel provides the rest. Evaluate based on both direct investment and donor investment. Compare those results with and evaluation of 100% CNO-powered diesel generation for the same size range.

- **Solar versus CNO for Kiritimati grids -** Fund a separate study of the same type but focusing on the specific needs of the several small grids on Kiritimati that follows on from the Kiritimati biofuel feasibility study prepared in 2011 using PIGGAREP funding. Determine which technological approach best fits the requirements of each existing grid.

SERVICE-RESOURCE V: CNO-BASED BIOFUELS FOR TRANSPORTATION

STATUS OF THE SECTOR

The KOIL estimates that about 12 million litres of all fossil fuels is used for transport. The fuel usage for inter-island shipping represents the bulk of the diesel fuel that is imported for transport purposes and appears to be about equal to the fuel used for power generation, though accurate statistics are not available. Currently both government and private ships provide passenger and freight services between islands or across the lagoon on an atoll. The majority of the inter-island vessels have diesel engines that could be adapted to use a percentage of CNO as their fuel. To date, in the Pacific Islands there have been a number of discussions and some proposals for the conversion of ship engines to CNO but no definitive trials.

Although there is no data regarding the relative amount of diesel and petrol use for land transport, there are an increasing number of diesel vehicles on the road besides the usual trucks and busses. The government in particular has been selecting diesel-powered vehicles both for their excellent fuel economy and their relatively low maintenance requirements.

ISSUES

- Unlike diesel generators on the grid, ship engines may be operated for extended periods at low power levels, such as while manoeuvring into port or while anchored. The carbon build-up seen in diesel engines burning fuels with a significant percentage of CNO is generally the result of low combustion chamber temperatures that occur at low engine loading. To accommodate a high percentage of CNO in engines that sometimes operate at low load levels, one simple approach used elsewhere has been to switch between two fuel tanks, one with biofuel that is only used when the engine is loaded above about 50%, and another filled with diesel fuel for low load conditions.

- A biofuel quality standard that is stringently enforced is more important for shipping than for power generation, since engine breakdown at sea can put the vessel and those aboard in serious danger. Therefore before committing to a high percentage of CNO for shipping, standards will need to established as well as a testing facility that can continually check to ensure that the standards are being maintained

- Work with the KOIL to establish biofuel dispensing sites for land transport following approval of biofuel standards and initiation of biofuel production.

RECOMMENDED ACTIONS

- **Testing facility for CNO as a transport fuel -** Development of a complete, independent biofuel testing facility that can assure ship and vehicle owners that delivered biofuel meets standards that have been set for CNO to be used as a diesel fuel replacement.

- **Shipping trial with CNO -** Prepare a project to retrofit an existing inter-island ship with two fuel tanks, one for diesel fuel and one for CNO, to allow switching to CNO when engine loading is high and to diesel fuel when loading is low and problems with carbon build-up could occur if CNO were used.

SERVICE-RESOURCE VI: LEGISLATION AND POLICY

STATUS OF THE SECTOR

The MPWU has primary responsibility for the planning, management and co-ordination of the energy sector. Other entities with energy sector responsibilities are listed below.

- The EPU co-ordinates the implementation of energy policies and provides advice and assistance on all energy-related matters and activities.

- The PUB is a government-owned body responsible for provision of power, water supply and sewage services to South Tarawa.

- The KSEC is a government-owned corporation responsible for the provision of electrical services to rural areas through the operation and maintenance of solar PV systems. It currently manages 224 kWp of solar for outer island residences, 47.6 kWp of solar for community buildings, 7.5 kWp for streetlights and 6.4 kWp for communications. In addition, it has contracted for the maintenance of solar pumps for the Public Works Department, health centre solar installations, school solar systems for the Ministry of Education and solar installations for schools of various church groups.

- The KOIL is a government-owned corporation involved in the purchase and distribution of petroleum products throughout Kiribati.

- The MLPD is responsible for all government services on Kiritimati and the populated Line and Phoenix islands.

LEGAL STRUCTURE OF THE ENERGY SECTOR

- The Public Utilities Ordinance (Cap 83 of 1977 revised 1998 and 2010) is the legislative basis for the formation of the PUB. It allows the MPWU to declare electricity supply and/or water supply areas as exclusive to the PUB for the provision of services. The ordinance was amended to provide more autonomy to the PUB. The PUB is currently acting as a parastatal body with its own terms of service and tariff management.

- Prices Ordinance (Cap 1975 and revised in 1981) includes price controls for petrol and kerosene. Diesel is not under price control.

- Petroleum Act (Cap 69) regulates safety, storage, rationing, and customs inspections.

- The Environment Act (Act 9 of 1999 amended in 2007) provides for the protection, improvement and conservation of the Kiribati environment. It is supplemented by Environmental Regulations 2001.

The Energy Policy was established in association with the Kiribati Development Plan 2008-2011 and has as its primary goals human resource development in the energy sector, development of livelihoods, energy security and energy access. The guiding principles are sustainability, gender equity, environmental compatibility, stakeholder participation, good governance and cultural/traditional compatibility.

With regards to renewable energy the policies include:

- Promoting sustainable renewable energy access;

- Ensuring that the limited biomass resources are used in an economic, environmental and culturally-sustainable manner;

- Strengthening collaboration with development partners for the advancement of renewable energy programmes;

- Promoting and encouraging the use of appropriate renewable energy technologies;

- Expediting the replication of successful solar programmes; and

- Introducing appropriate incentive packages including taxes, duties and tariffs to encourage the use of renewable energy technologies.

ISSUES

- What is the role of the private sector in developing renewable energy in Kiribati? Should the KSEC be privatised? What about private preparation and distribution of biofuel? What about private solar or wind generation feeding into the grid? What legislation, policies, incentives and regulation are needed for private sector development?

- What are the policy and legislation gaps that may cause problems for the future as the use of renewable energy increases? Although the Kiribati Energy Policy is relatively recent, there may be areas that need improvement to best promote the use of renewable energy to reduce the import of fossil fuels.

- What additional institutional structures or changes in existing ones are needed to best support renewable energy in Kiribati?

- What renewable energy standards and design guidelines are needed to assure that all installations can be sustained by Kiribati institutions? How will training to meet standards be delivered and to whom? Who should enforce the installation and design standards?

RECOMMENDED ACTIONS

- **Establish a stakeholder-based co-ordinating committee for energy development co-ordination -** Establishing a Kiribati National Energy Co-ordinating Committee (KNECC) to oversee the development of programmes and projects intended to reduce dependence on fossil fuels including the implementation of National Energy Policy, Action Plans and projects is recommended. The Secretariat of the KNECC should be the EPU however capacity building will be required for effective delivery of its co-ordination role.

- **Review of the existing regulatory and policy situation -** Reviewing policies, acts and regulations will help determine where there are disincentives for the use of renewable energy and what incentives can be introduced. There is a need to review the existing Customs Act to create incentives to import and retail renewable energy components to the outer islands by private businesses to increase access to solar energy in the rural areas. The current tax on importation of renewable energy technologies such as solar panels and batteries is 30% for the private sector while government projects are exempted from this tax. Establishing net metering policies and standardised power purchase agreements may also facilitate the private sector in delivering renewable energy-generated power to the grid. The limited coconut stock for biofuel use for electricity and transport is a challenge and therefore there is a need to revise policies related to the rehabilitation of the coconut industry.

- **Review the KSEC business model review -** The KSEC business model and its status need to be reviewed. The KSEC is a government entity responsible for improving access of renewable energy to rural and outer islands. Only 31% of the total population in the outer islands have access to SHS while 5% use other means of obtaining power.

- **Establish standards and guidelines for renewable energy development –** The first stage is determining what renewable energy standards and design guidelines are needed for off-grid and on-grid installations. Currently there are no existing standards relating to the technical and safety issues for renewable energy electricity generation. The lack of electrical standards is also a barrier to developing the capacity of locals in electrical technology. Once needed standards are identified and developed, there is a need to set up a regulatory body to ensure that the technical and safety standards and guidelines are properly followed. The MWPU should serve as a technical regulatory body to oversee the enforcement of these standards. Standards for off-grid or stand-alone solar systems have been established, however these should be disseminated and standardised for private sector use.

- **Create a more comprehensive omnibus act for energy –** There is a need to develop an 'Energy Act' that provides legal mandates for the institutional reforms necessary for the development of renewable energy to replace imported fossil fuels. This act will also fill in gaps in earlier legislation.

Following the completion of the RRA workshop, discussions with stakeholders were held that considered the setting of goals for fuel import reduction. It was decided that there should be separate goals for fuel import reduction for Tarawa and for Kiritimati, since the two energy systems are very different and not inter-related. After due deliberation, the goals were set as follows:

TARAWA GOAL[13]

The goal for Tarawa is that the percentage of energy coming from fossil fuels for electricity generation will be reduced by 45% through a Business As Usual (BAU) model by the year 2025. It is anticipated that solar energy and biofuel will be the dominant renewable energy sources used to achieve this goal. The goal is for electricity from renewable energy to reduce fuel imports by 23% by 2025. The goal for energy efficiency, both on the supply and demand side is the reduction by 22% in demand through the BAU model.

KIRITIMATI GOAL

The goal for Kiritimati is to reduce by 60% the energy coming from fossil fuels for electricity generation by the year 2025 through the BAU model. A 100% reduction is to be achieved by 2030 through increased production of CNO. It is anticipated that solar energy and biofuel will be the dominant renewable energy sources used to achieve this goal. The goal is for electricity from renewable energy to reduce fuel imports by 40% by 2025. The goal for energy efficiency, in both the supply and demand sides, is the reduction in demand by 20% by 2025 through the BAU model.

OUTER ISLANDS GOAL

For the outer islands, it is proposed that a government policy be put into effect that requires all electricity generation expansion to be through renewable energy. The policy would also mandate that existing IC, government and school diesel generation be converted to renewable energy by 2025. Thus by 2025 all electricity generation on the outer islands will be through renewable energy.

These proposed goals have been submitted to the Kiribati Cabinet for review and approval.

13 The terminology of "goal" that was used in the proposal to Cabinet actually indicates a target to be set

IV. Summary of Recommended Actions

The following schematic identifies the recommended actions from the RRA process. These actions are not presented in any order of priority, and the list of actions from a rapid assessment is unlikely to be exhaustive. The detailed list of actions can be found in Annex.

Maintain the stability of the grid while allowing a high level of solar PV input	☼ Coordinate the WB and the PEC Fund solar projects so both take responsibility for their combined projects to prevent endangering grid stability. ☼ Develop standards and guidelines for future solar PV grid-connected systems. ☼ Investigate the appropriateness of privately-owned grid-connected solar PV. ☼ Facilitate capacity building to manage grid stability with high levels of solar penetration.
Develop CNO as a biofuel for power generation	☼ Prepare a CNO implementation plan for Kiribati to determine the specific actions and timelines necessary to develop CNO as an acceptable diesel fuel replacement. ☼ Establish fuel standards and a testing facility for CNO-based biofuel to be used for power generation and transport. ☼ Develop mobile copra mills for use on Kiritimati and outer islands. ☼ Have the PUB procure a genset designed for use with CBI for base load generation.
Use of CNO as a land and sea transport fuel	☼ Trial of shipboard use of CNO through the dual tank system. ☼ Trials of blends of CNO and kerosene or diesel fuel for land transport.
Off-grid electrification including Kiritimati	☼ Prepare an outer islands electrification implementation plan that only uses renewable energy. ☼ Prepare standard modular design and installation guidelines for solar powered mini-grids. ☼ Develop a local off-grid electrification capacity building facility at the KIT. ☼ Provide for rehabilitation of existing outer island solar installations. ☼ Determine how the KSEC can be institutionally strengthened. ☼ Increase private sector involvement in renewable energy development
Policy, legislation and regulation development to support renewable energy	☼ Establish a Kiribati National Energy Coordinating Committee. ☼ Review existing incentives, regulations, and policies relating to energy and propose changes where there are disincentives for renewable energy. ☼ Prepare an "Energy Act" that fills the gaps in current legislation. ☼ Review the KSEC business model.

V. Best Practices in Kiribati

SOLAR UTILITY (RENEWABLE ENERGY SERVICE COMPANY) STRUCTURE FOR OUTER ISLAND SOLAR ELECTRIFICATION

Probably the most difficult problem in implementing solar energy for residences located in remote areas has been the creation and establishment of a suitable institutional structure that can provide for sustainable, affordable and reliable electricity access through SHS to meet the needs of remote rural households.

Since the early 1980s, the Kiribati government has focused on renewable energy for the outer islands and has specifically avoided using diesel generation for electrical power. To support that policy, the Kiribati Solar Energy Company (KSEC) was established under USAID funding in 1984 to act as an importer and seller of SHS for outer island households. The programme included technical assistance in the selection of components to meet the needs of the buyer, clear local language instructions on how to properly install the systems and technical advice in case there are problems with the system. The initial response was strong, with over 250 systems sold by 1987. But that was the peak for sales, with a rapid and constant decline after that until the KSEC faced bankruptcy in 1989, despite an injection of additional funds from USAID. A survey carried out by the Forum Secretariat Energy Division, the regional energy agency at that time, showed clearly that the reason for the rapid decline in sales was a decline in market confidence in the technology, not market saturation. The equipment purchasers chose undersized panels and batteries to save cost, installed the equipment using wire that was too small and made connections that were just twisted wires or alligator clips. There was little or no maintenance of the batteries. The end result was low power reliability and great customer dissatisfaction. As the word of the problems spread through the close-knit island communities, sales dried up.

At the request of the Kiribati government in 1989, a consultant was brought in to help determine how the KSEC could be re-organised to better achieve the goal of rural electrification through renewable energy. After lengthy discussions and analysis, it was decided to establish a solar utility that would operate along the lines of conventional utilities, whereby all equip-ment was owned by the utility and all maintenance was done by the utility, with the customer's only responsibility being the payment of a periodic fee. The JICA agreed to fund a trial of the concept using the North Tarawa rural area as the location, since it was relatively easily accessed and had all the characteristics of an outer island rural area. By 1992, over 50 homes on North Tarawa were provided electricity through the KSEC Utility structure. Based on that trial a number of lessons were learned:

- Hands-on training and continued training, preferably at least annually, is essential to quality maintenance.
- Although young people tend to be better at technical tasks, it was found that the community responded better to technicians who were older in age. The reason for this is that they are more respected in the community and appear to have a greater sense of their responsibility. Also, as their main tasks are dealing with customer problems, not technical problems, they have been more successful at fee collection and securing customer co-operation.
- Only the most robust quality components should be installed in remote sites. The cost of replacing batteries and other components is very high due to access costs, so the more reliable the system the lower the life cycle cost.
- Simplicity is important to reliability. The local technician has to be able to easily adjust and repair the installations.
- There needs to be careful control of spare parts on the island. There is a continuing temptation to use spare parts to construct new systems for the free use of friends and relatives of the technician
- Fees must be checked and if needed re-adjusted at least annually to provide for sustainable operations.
- Administration needs to be dispersed not centralised. Central administration is expensive and not very effective, since it is not cost effective or administratively efficient to supervise the outer island agents from Tarawa. The central office needs to concentrate on corporate policy and its enforcement, spare parts purchasing and their central storage, new project development, component manufacture, and interactions with the national government.
- Clear standards and guidelines for installations, component purchasing and administration need to be established and insisted upon in donor funded projects. Many of the problems currently facing the KSEC are the direct result of poor technical and business advice that was provided in association with donor projects.

LOCAL MANUFACTURE OF SHS CHARGE CONTROLLERS AND DC/DC CONVERTERS FOR OPERATING RADIOS OFF SHS BATTERIES

A serious problem for maintenance of SHS in remote areas has been charge controllers. As was seen in a multi-year test series carried out in Tahiti in the late 1980s, commercial charge controllers are not designed to meet the demanding environmental conditions of atoll islands and typically will not survive for more than a few years. This is still the case for the new versions of commercial charge controllers, primarily due to the increasing complexity of controller design particularly using microprocessor-controlled switching units. The life of commercial controllers seems to be typically 3 to 5 years on atoll islands where the environmental effects are probably the worst. In Fiji they seem to perform a bit better but still not even close to the very long life of the Kiribati manufactured controllers.

A number of issues causing the failure have been identified. The first is an increase in temperature sensitivity with increasing failure rates seen at higher ambient temperatures. The simple on-off relay type controller is not affected negatively by higher ambient temperatures and the need to put the controller, battery and panel all in one outdoor unit that gets fairly hot (as it is in the sun) is not a problem for the locally made controller but is a problem for semiconductor switching units.

The second cause is that none of the current controllers that use microprocessors can be tested in the field without expensive equipment and a great deal of training for the field technicians. Although some modern controllers have a built-in 'self-test' routine but if the microprocessor is not working appropriately, the reliability of "self-test" function and results is questionable. The newer versions of controllers generally use Pulse Width Modulation (PWM) and tapered charging and have elaborate algorithms for managing the charge. In theory this can increase the quality of charging, in practice the units may fail to work at all due to environmental problems and any charging benefits are lost as a result.

Furthermore, manufacturers neither provide technical support for troubleshooting or repair, nor share schematics of the circuitry to prevent cloning by local manufacturers. Consequently, all malfunctioning chargers have to be returned at great expense to the manufacturer for repairs or else are thrown away and simply replaced with new units. Finally, most commercial units employ circuitry that cannot be tested in the field for proper operation, so field technicians are unable to properly troubleshoot the installations, since the charge controller may be a source of several different types of system problems. Also for remote sites, the replacement of a failed charge controller may take weeks or even months, during which time the battery is not being properly charged and is often damaged in ways that shorten its life.

In order to avoid these problems, the SPIRE, as part of its mandate to test and design robust solar components and systems for island use, created a special design for a charge/discharge controller that would be simple to build, simple to test and simple to repair while surviving for many years in the atoll environment. The controller design was first used in the mid-1980s in the Tuamotu atolls and was found to have much fewer failures and operational problems than commercial controllers. When the EU "PV-Follow-up" project of the Lomé II funding series was established to provide SHS to Kiribati, Tonga, Tuvalu and Fiji, the KSEC opted to locally manufacture the SPIRE controller for use in the project. The controller uses relay switching instead of semiconductors, an approach that separates the panel to battery circuit from the control unit so induced voltage spikes in the panel to battery circuit caused by nearby lighting strikes are not damaging. The unit uses very simple yet accurate discrete component voltage comparator circuitry to provide the on-off control for both the charge and the discharge control sections. It generates no heat and therefore does not need ventilation and operates without problems at temperatures well in excess of those that would be detrimental to semiconductor switching units. There are no integrated circuits so the common problem of a salt-dust-moisture bridge forming in the very small space between integrated circuit connections and causing a malfunction is avoided. During the decade following the EU project installations, less than 1% of the installed controllers had problems and most of those were due to improper actions by local technicians rather than component failures. Battery life for installations with the locally made controllers was excellent, often exceeding 10 years.

Since the controllers were built locally from loose parts and were tested and adjusted by local staff, maintenance and repairs were easily accomplished. Testing of the controllers can be done in the field with simple test equipment, so field technicians can learn how to test for the proper actions of the controller. Furthermore, by removing the discharge relay, the controller can continue to maintain charge in the battery when power to the customer is disconnected – an action needed if there is to be disconnection for non-payment of fees or if there is a need to work on the wiring in the residence. To set the system to equalise the cells in the battery, pulling the plug that provides power to the voltage comparator directly connects the panels to the battery, allowing the field technician to do a controlled overcharge for equalisation.

Also part of the Kiribati system (though not part of the installations delivered under the EU project) is a high efficiency DC/DC converter that uses switching transistor circuitry to deliver the proper voltage to customer's radios or tape players, which are typically 4.5 V, 6 V or 9 V. The design and kits of parts were provided by Plasmatronics, an Australian solar electronics company, and were assembled by the Solar Energy Company.

Lessons learnt follow:

- High reliability charge controllers and DC/DC converters for SHS can be cost-effectively manufactured by local technicians in the islands.
- Training for the manufacture of the devices need not be complex or expensive.
- It is best to not use only one quality control step in manufacturing electronic devices; rather use at least two, with an initial setting by one technician and a check by a second technician.
- By using a design specifically created for the atoll environment and the end use, much longer service life and higher reliability can be achieved.
- High reliability controllers result in longer battery life and lower life cycle costs.

VI. Future Co-operation

The RRA is just the first step towards preparing a comprehensive action plan to reach the goals for renewable energy that are being set by the Kiribati government. As the lead agency in assisting Kiribati to reach their renewable energy goals, IRENA plans to assist in co-ordinating donor agencies; developing funding for projects; co-ordinating the efforts of the WB and the PEC Fund to implement their grid-connected PV projects in a way that will not adversely affect grid stability; assisting in capacity building where needed; sharing experiences from other parts of the world; and supporting Kiribati leaders' attendance of meetings and workshops where high level persons from around the world meet to discuss the future of renewable energy and its implementation today.

Another important follow-up lies in setting targets to reduce fuel import dependence. Following the RRA, the Kiribati EPU has prepared detailed targets for renewable energy development. Since the EPU also considers energy efficiency an important measure to reduce the consumption of imported fuels, the MPWU took advantage of the momentum from the RRA workshop and funded a third workshop to begin development of an action plan for energy efficiency in Kiribati. From that effort, targets for energy efficiency improvements were also prepared. At present, the proposed targets have been submitted to the Kiribati Cabinet for final approval. It is expected that the national targets will be approved in near future.

In order to reach the targets that have been set, energy planning is crucial. It is a process requiring multi-stakeholder consultation and co-ordination, the capability of developing different energy scenarios, the human resources to effectively develop and implement a concerted plan, and all areas that can be assisted by IRENA. Kiribati will need to establish a national institution responsible for co-ordinating the different governmental agencies on energy related issues and strategy making. This may also present an opportunity for IRENA to provide support to Kiribati in terms of sharing the best practices of energy planning and also facilitating the set-up of such a co-ordinating entity.

In addition, there is great opportunity for IRENA to be engaged in capacity building in Kiribati. It is an area where IRENA's support can be impactful if done well and is an area where IRENA has the capacity to make a difference. IRENA in concert with the WB, ADB, SPC, GiZ, JICA and other development partners, hopes to work further with Kiribati to help develop its capacity to carry out the planning, implementation and management of programmes needed to reach its renewable energy goals.

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Great care was taken to obtain as much data and information as possible from primary sources. Some was obtained through written questionnaires, some through interviews and some through email correspondence. Data relating to energy statistics was obtained from the EPU. Data relating to power generation was obtained from the EPU and the PUB. Data relating to CNO, copra production, coconut tree cover and the extent of senile coconut trees came from presentations made by officials of the Kiribati Copra Cooperative Society. Data regarding trials of CNO in Kiribati was provided by the KCMCL and statistical and demographic data was provided by the Kiribati National Statistics office of the Ministry of Finance.

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VIII. Annex

Action 1

Improve policies, legislation and regulations
to support the use of renewable energy

Resource-Service pair(s)	Policy support for development of renewable energies
Description	The 2009 Kiribati Energy Policy may require changes to better promote the use of renewable energy and reduce the import of fossil fuels. This is particularly true when it comes to the large-scale deployment of renewable energy sources, as well as the role that the private sector can play in renewable energy development in Kiribati. The policy and legislation gaps must also be dealt with that otherwise may cause issues in the future as the use of renewable energy increases. Therefore, the following key initiatives need to be taken. ☼ Establishing a Kiribati National Energy Co-ordinating Committee (KNECC) to oversee and guide the development of programmes and projects to reduce dependence on fossil fuels, including the implementation of the National Energy Policy, Action Plans. ☼ Conduct a review of the existing relevant regulatory, customs duties, taxes and policies to determine the optimum way to promote the increased use of renewable energies and to replace fossil fuel usage. This is to include the development of new regulatory schemes and policies that may be appropriate, such as net metering and standardised power purchase agreements, to facilitate the private sector in delivering renewable energy-generated power to the grid. ☼ Establish standards and guidelines for renewable energy development including on-grid and off-grid installations, and CNO biofuel production; to minimise the cost of installation and maintenance; and minimise issues relating to the technical and safety characteristics of such installations.

	☼ Continue developing an on-going strategy to achieve the renewable energy goals approved by Cabinet.
Actors	Ministry of Public Works and Utilities, Ministry for Finance and Economic Development, Ministry of Environment, Lands and Agriculture Development, Ministry of Commerce, Industry and Co-operatives, Ministry for Communications, Transport and Tourism Development, Public Utilities Board, Kiribati Solar Energy Company, Office of the President, Attorney General's Office, Kiribati Chamber of Commerce and Industry, Kiribati Institute of Technology, development aid partners.
Timeframe	The estimated timeframe is 24 months.
Keys for success	The development of consensus and strong commitments from key stakeholders is a precondition of this action. The success will also subject to the following factors: ☼ Effective co-ordination and collaboration among the key stakeholders; ☼ Secure endorsement and continued support from high level officials; ☼ Accessibility of all relevant information and data for policy evaluation and improvements; ☼ Availability of financial and technical support from development aid partners.

Action 2

Achieve high penetration of grid-connected solar photovoltaic (PV) installations

Resource-Service pair(s)	Solar energy for electricity (on-grid)

Description

In order to meet Kiribati's goal of being energy independent, solar energy will have to play an important role. Although off-grid small-scale solar PV systems have been in use in Kiribati since the 1970s, knowledge and experience in large-scale grid-connected solar PV applications is limited. Since the emerging issues on grid integration stem both from the technical aspect and the current institutional, capacity and legislative environment, a systematic perspective and approach is needed to mitigate any negative impacts on grid stability and performance. Key initiatives under this action to address these issues include:

- Continue to work together with the WB and the PEC Fund solar projects, so that both take responsibility to prevent their combined projects endangering grid stability. The co-ordination shall facilitate a full-range of exploration of technical options for ensuring future grid stability including adding energy storage.

- Conduct a further grid stability study that includes a detailed modelling of the grid needs to be conducted to assess what technologies are appropriate to install and thus ensure the grid can take additional variable energy sources (solar and/or wind) after the WB and PEC Fund installations are in place.

- Develop standards and guidelines that are in compliance with international standards and are appropriate to the island environment.

- Facilitate capacity building for the staff of the Public Utilities Board in managing the grid with a high level of solar penetration.

- Investigate the appropriateness of privately-owned grid-connected solar PV and of introducing net-metering in this context.

Actors	Ministry of Public Works and Utilities, Public Utilities Board, Kiribati Solar Energy Company, and development partners like IRENA, World Bank, and Pacific Environment Community among others.
Timeframe	All the four initiatives can be implemented in parallel. The estimated timeframe is 24 months.
Keys for success	Development of sufficient capacity to manage grid-connected solar PV installations within Kiribati, and the establishment of a strategy for Kiribati to address the grid integration issues in a systematic manner. ☼ Use appropriate tools to evaluate the grid stability under different scenarios; ☼ A wide range of technological options that can be adopted to address the stresses posed by variable energy sources should be examined, including those which are developed by local technicians. ☼ The capacity building programmes should be jointly developed in co-operation with relevant international and national partners to ensure the effectiveness of the programmes. o Availability of financial and technical support from development partners.

Action 3

Develop a strategy for partly substituting diesel fuel with coconut oil biofuel (CNO)

Resource-Service pair(s)	Biofuels for power generation and transportation

Description

Utilisation of CNO as a substitute for diesel fuel is important since its usage does not introduce grid stability issues. However, there are other issues associated with use of CNO for power generation, notably the compatibility of existing engines. To date, there have been a few trials of CNO for diesel power generation in Kiribati and regionally there have been a number of experiments and successful use of a blend of CNO and diesel fuel in large engines used for power generation and transport. This indicates that the issues associated with engine compatibility, CNO biofuel quality and feedstock supply can be successfully addressed if a holistic approach is adopted. To this end, a strategy for electric power generation using CNO biofuel applications needs to be developed as the first step for Kiribati to move forward in the use of CNO to partially substitute diesel fuel for power generation and transport. This strategic action plan includes the following key activities:

- Evaluate the supply chain of copra as feedstock for production of CNO biofuel and plan for the replantation of senile coconut trees to meet the potential demand growth for copra production.
- Conduct a feasibility study on the use of small-scale, mobile crushing mills for the preparation of adequate quality CNO for biofuel on outer islands and Kiritimati; and determine the appropriateness of the use of mobile crushing machine when compared with the existing CNO production chain.
- Prepare and Implement quality standards for the CNO.
- Establish a CNO oil testing facility in Kiribati to ensure the quality of CNO is adequate for biofuel that is used for power generation and transport.
- Trial of shipboard use of CNO through the dual tank system.
- In association with Kiribati Oil Company (KOIL), carry out trials of blends of CNO and kerosene or diesel fuel for land transport.

Actors	Ministry of Public Works and Utilities of Kiribati, Kiribati Copra Mill Company Limited, Kiribati Copra Co-operative Limited, external technical assistance providers and development partners
Timeframe	The entire timeframe for this action is estimated to be 18 months
Keys for success	Development of a better understanding of feedstock supply chain and determination of the critical path for CNO production; ☼ Actions by copra farmers to prepare for the increased demand for copra as feedstock for production of biofuel; ☼ Development of a price structure for copra production that is acceptable to farmers and end users of CNO. ☼ Ability of oil producers to meet the required quality standards. ☼ Availability of financial and technical support from development partners.

Action 4

Strengthen and promote off-grid solar applications

Resource-Service Pair(s)	Solar energy for electricity (off-grid)
Description	The current estimate is that over one-third of the approximately 2 200 outer island solar installations, mostly Solar Home System (SHS), are no longer working due to the lack of battery replacements. A detailed plan for rehabilitation of the off-grid solar installations was prepared by the KSEC in conjunction with the Kiribati government. However, questions such as how to best address the rehabilitation of the outer island solar installations, or what rural electricity model using off-grid solar PV installations best meets the needs of rural Kiribati, i.e. stand-alone SHS, small lighting 'kits', or mini/micro-grids, remains to be determined. The following initiatives will look to answer these questions and others, to develop for Kiribati the best approach for future off-grid solar applications.

- Prepare an outer islands electrification implementation plan that only uses renewable energy, including the rehabilitation of existing outer island solar installations. The plan should also elaborate the expansion of solar electricity installations for rural households and maneabas. The plan should be based on a carefully prepared survey of rural energy needs, the willingness and ability of residents to pay for the services to meet those stated needs, and effectiveness of the current operation and maintenance system compared with other business models for the KSEC.

- Prepare a standard modular design and installation guidelines for solar powered mini-grids, include the practical management and operational models that best fit the local context of rural Kiribati.

- Determine how the KSEC can be institutionally strengthened that will enable it to better meet the maintenance needs of the rural solar installations under its control.

- Determine if resources are better used to establish separate technical maintenance crews within each organisation having solar installations – notably health, education, water supply and private schools – on outer islands, or should a

	specialist organisation, such as the KSEC or a private company, develop the capacity to contract for all outer island solar maintenance. ☼ Develop a local off-grid electrification capacity building facility at the Kiribati Institute of Technology (KIT).
Actors	Ministry of Public Works and Utilities of Kiribat, KSEC, organisations with outer island solar installations and Development aid partners
Timeframe	The estimated timeframe is 14 months for this action.
Keys for success	Rigid study and evaluation of the requirements for the operation and maintenance of existing and planned off-grid solar applications ☼ The technical designs and capacity building programmes must be developed in the context of conditions in rural Kiribati; ☼ Availability of financial and technical support from development aid partners.

Action 5

Determine the best roles for the available renewable energies in Kiritimati's power development.

Resource-Service Pair(s)	Renewable energy for Kiritimati development

Description:

The existing power system on Kiritimati includes a number of small independent diesel powered grids. Some of these are planned to be interconnected to provide a larger, more robust electricity supply for the main population centres. However, several of the small independent grids will remain stand-alone power systems since the cost of interconnection cannot be justified due to the small loads involved and the distance from those small grids to the main population centres. The long-term goal is for Kiritimati to have 100% renewable energy for electricity production and, where possible, also for transportation. Wind energy has been determined to be a practical resource and solar energy is already being used successfully on Kiritimati to reduce fuel use in the London grid. There are a large number of coconut trees and the Ministry of Environment, Lands and Agriculture Development has prepared a replanting project to increase coconut production. Therefore CNO is also expected to be a useful renewable energy resource. Currently, however, there is no oil mill on Kiritimati and the cost of shipping of copra to Tarawa and the resulting oil back to Kiritimati significantly increases the cost of CNO on Kiritimati, therefore some form of local oil production appears to be necessary.

To make the best use of available resources, the following actions need to be taken:

- Prepare a detailed study for the near-term and long-term power development of the main grid on Kiritimati to maximise the use of renewable energy in the most cost effective and sustainable manner.
- Determine the most cost effective and sustainable approach to converting the remaining small grids to 100% renewable energy.
- In order to solicit funds from development partners for the development of the primary grid on Kiritimati, prepare a detailed design and associated project documents for the implementations necessary to follow the power development plan that is developed.

	- Prepare detailed designs and project documents for the conversion of the remaining diesel powered micro grids to renewable energy in a manner that is sustainable and economically appropriate. - Prepare a plan intended to ensure that the maximum amount of fuel used for transport on Kiritimati will have a renewable energy source within the next ten years. - Develop and maintain the human capacity on Kiritimati needed to carry out the required installations and sustain them for the longer-term through a Kiritimati located public or private training institution – such as a training division under the organisation that operates and maintains the renewable energy systems or through a local branch of KIT or USP.
Actors	Ministry of Line and Phoenix Development, Ministry of Public Works and Utilities, Kiribati Institute of Technology, development partners and key stakeholders on Kiritimati
Timeframe	The estimated time frame is 24 months
Keys for success	Development plans for all energy used on Kiritimati are prepared collaboratively and not individually, to avoid competition between development projects for the limited resources available on Kiritimati; - Effective co-ordination, collaboration and co-operation among the many stakeholders; - Secure endorsement and continued support from high level officials of the Kiribati Government; - Availability of appropriate financial and technical support from development aid partners. - Capacity building and long term capacity maintenance needs are made available on Kiritimati

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